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"Human-Engineering" Aspects of Safety

By R. A. McFARLAND. (From *Mechanical Engineering, U.S.A.*, Vol. 76, No. 5, May 1954, pp. 407-410.)

Engineering and biological sciences are being integrated in the field of study referred to as "human engineering," a primary objective of which is to improve safety by designing equipment in terms of human capabilities and limitations.

THE "human-engineering" approach to the solution of the accident problem is to build machines and working areas around the operator, rather than to place him in a setting without regard to his requirements and capacities. Unless this is done, it is hardly fair to attribute so many accidents to human failure, as is usually the case.

The importance of the problem is evident from the fact that one of the major causes of death and injury in both military and civilian populations relates to accidental injury. The loss of life and incapacity resulting from accidents are as great as or greater than loss and incapacity from any known disease entity. In the U.S.A., accidental injury ranks first as the leading cause of death for persons between 1 and 24 years of age, and second for those between 25 and 44 years. The fact that these victims are in the younger age groups, in contrast to those whose deaths are attributable to certain degenerative diseases, implies an enormous cost to the productive resources of the country in terms of life-years.

One of the most important ways of improving safety is to design equipment in terms of human capabilities and limitations. It should be remembered that radios do not hear, radar does not see, and guns do not point, any more than automobiles drive themselves. Difficulties arise when mechanisation becomes too complicated for human operators.*

More precisely stated, the engineer must have an understanding of the sense organs and the characteristics of human perception, if satisfactory information is to be supplied from sounds and lights in the operation of equipment. In general, man is a poor monitor of equipment. Also, the engineer must not place unreasonable demands upon the operator with regard to the physical responses involved, i.e., in reaching or operating controls or levers, or in clearly differentiating between them; otherwise, inadvertent operation of a switch or control may occur. Furthermore, the engineer must consider that the operator of equipment is frequently suffering from temporary impairment of functions, causing inefficiency, such as fatigue, and that there may be changes in function as a result of ageing. Finally, physiological and environmental conditions, such as temperature, humidity, toxic gases, altitude, and other factors, must be considered, or physiological limits may be exceeded.

All possible faults in equipment, as well as the capacities of the operator, should be subjected to an advance analysis for preventing accidents. Advance analysis assumes the following considerations:—(1) An operational job analysis, which should include a survey of the nature of the task, the work surroundings, the location of controls and instruments, and the way in which the operator performs his duties. (2) A "functional concept of accidents," in which errors that may occur while the operator is working at the machine are anticipated. The repetition or recurrence of near or real accidents clearly indicates a need for redesigning. (3) "Human limitations." It should be assumed that no operator is perfect. In fact, he may be far below the ability adjudged by the designer. If his duties are too complex, the cumulative burden is great and he reaches or exceeds his limits of attention and ability.

Finally, a wide margin of safety should be provided, to eliminate any possible situation which places the operator near his maximum ability with regard to aptitude or effort, especially when adverse factors enter the picture.

One of the first steps in ensuring safety on the job is to make an analysis of what is required of the individual and to study the more critical features of each job. Many accident potentials can be revealed by this procedure. Each type of equipment and its operation must be subjected to thorough study and interpretation, in order to understand what is expected of employees. Techniques involving "near accidents" are often revealing, and minor incidents should be recorded and interpreted.

LAYOUT OF WORKING SPACE

In order to improve the ease, efficiency, and safety of operation of all types of equipment, consideration should be given to the application of anthropometric data to design, and to its use in a dynamic setting. In many instances, an engineer is given instructions to design the equipment and the operator's area in such a way as to "prevent reaching beyond range of vision," "avoid off-balance positions," and "provide adequate headroom and clearance." Rarely is he supplied with quantitative descriptions to meet these requirements.

On the other hand, if quantitative measurements are provided, the "average-value" fallacy is often committed. Although such values can be applied to special cases in the design of equipment, arrangements based on averages would be unsuitable for 50% of the operators in a normally distributed group.

Instead of averages, percentile distribution tables should be used, showing the measurements for given human dimensions in tabular form for each 5% of the population, from the smallest or 5th percentile to the largest or 95th percentile. Thus, by choosing the fifth percentile as the minimum and the 95th percentile as the maximum, a machine may be designed to fit fully 90% of the population—a desirable practice.

DESIGN AND ARRANGEMENT OF CONTROLS AND DISPLAYS

The concept of design failure is relatively new and unexplored, partly because accident reports have failed to identify design failure. Design failures may be so subtle that those responsible for reporting the accidents may not even be aware of them, particularly if they are not trained to recognise such failures.

With regard to controls and levers, many errors can be prevented if they are so designed and located that rapid and accurate judgment and movements can be made. In the design of controls, particular attention should be given to the shape and colour-coding of knobs,

* STEVENS, S. S.: "Machines cannot fight alone," *American Scientist*, Vol. 34, No. 5, 1946, pp. 389-400.

the radius of knobs and winding handles, the gear ratio, and the amount of friction and inertia.

Some of the important factors relating to the operation of controls are (1) their location for ease and accuracy of reaching, (2) direction of movement for greatest efficiency, (3) speed required in relation to rotary and wrist movements, (4) rate of movement from point to point, and (5) rate and accuracy of positioning responses. Unless controls are designed carefully, located properly, and identified easily, they are apt to be operated inadvertently. The design criteria for many of these variables have been determined experimentally for aircraft, and similar techniques in studying automotive equipment are now being used.

Another idea meriting study is that concerned with the design and location of switches and dials. The fundamental principle is to make the various switches of different sizes and shapes, in order to eliminate errors in identification.

With regard to visual displays, accidents may occur if an operator does not clearly perceive the location or movement of indicators, meters, or dials. A worker must receive clear information concerning his equipment, especially if several tasks must be performed successively or simultaneously for long periods.

The following factors have a significant effect on ease of seeing :—(1) Size and spacing of critical detail, especially in instrument markings and figures; (2) contrast between object and background ; (3) amount of illumination, including the use of colour ; and (4) contrast between the objects to be seen and their surroundings.

Auditory signals should be recognisable against the background of the sound pattern, and attempts should be made to use a range where the ear is maximally sensitive with respect to frequency, intensity, and duration.

Environmental Factors

Additional factors influencing the efficiency and safety of workers relate to the physical variables in the environment. These may be broken down into temperature, humidity, ventilation, noise, and vibration. Extremes of any of these factors will result in discomfort and lowered efficiency, as well as the discontent of employees. For each of these variables there are reasonably well-defined ranges of comfort and discomfort.

A summary of the various stimuli influencing worker comfort and safety, in terms of desirable and maximum values, is presented in Table I. Discomfort might be expected to arise if the limiting values given are not observed.

Table I. Variables Influencing Comfort and Safety.

Variable	Value for comfort
Ventilation	20 cfm of fresh air, min. per person.
Air temperature ..	70–72° F dry bulb, max.
Air velocity ..	40–60 fpm.
Humidity	25–50% relative humidity.
Carbon dioxide ..	0·5–1·0%, max.
Carbon monoxide ..	0·003% max.
Noise	80–85 db overall, and 30–60 db in 1200–2400 band, max.
Vibration	0·002 in. max. at 20 cps or more.

The values indicated in the table cannot, however, always be considered as rigid standards, because of the interdependence of one variable with others.

Inherent Deficiencies in Operators

Since design factors can remove only certain types of accident-inducing situations, it is also necessary to approach the problem from the point of view of deficiencies inherent in the operator. For this reason an attempt should be made to determine whether some individuals are apt to be more liable or " prone " to accidents than others and have higher accident rates.

Studies of such individuals involve the determination of whether there are important differences between individuals in their accident liabilities, and, if differences do exist, the devising of methods for detecting those individuals who are especially liable to accidents. Individuals having repeated accidents are often impulsive, aggressive, and resentful of their superiors.

Physical Standards for Selection

In the development of physical standards for selection, there has been disagreement, not only as to whether they should be more strict or more lenient, but also as to the functions to be measured and the tests to be used. Those who argue for greater leniency point to the lack of relationship between the findings on the physical examinations and accidents. The view presented here is that these questions can be answered only if the physical standards and tests are functionally related to the requirements of the job, and if the tests measure these functions accurately and consistently, i.e., are reliable, and are evaluated against some objective criterion of proficiency, i.e., are valid. After determining what a man is expected to see and hear or what stresses he may encounter, the various tests in the physical examination can be directed towards these requirements.

Few systematic attempts have been made to integrate physical standards with the requirements of the job. In aviation, for example, tests for hearing have been given in quiet rooms, where a pilot's ability to hear the required signals or speech in the presence of aircraft noise may or may not be appraised. In the case of older, more experienced pilots, some leniency should be permitted, inasmuch as those with hearing losses have more normal hearing in the presence of noise on the aircraft. Older pilots with hearing losses should therefore be tested in simulated aircraft noise. If the hearing losses do not interfere with intelligibility of normal conversation, safety would not be compromised.

Psychological Standards for Selection

The initial step in a successful selection programme involves a precise description of each job as it relates to the requirements and abilities of workers. In more complex jobs it is not sufficient merely to catalogue the various movements and tasks expected of the operator, but more particularly the sense of timing and the ability to understand subtle cues, to make judgments, and to anticipate future situations should be investigated. The ability to maintain emotional control under operating conditions must be evaluated.

Significant information can be obtained from recorded materials, such as training manuals and personnel files, interviews with those who possess an intimate knowledge of the job, analysis of direct experience by sampling methods, and objective techniques, such as wire recorders and motion-picture photography.

In order to arrive at a well-rounded evaluation of an applicant's psychological make-up, appraisals of proficiency on several traits should be made. This involves the development of a group or battery of tests based on accurate job descriptions, and of a valid success/failure criterion.

Numerous statistical techniques are available for obtaining the best possible groupings of such tests, so as to arrive at an overall evaluation of a candidate. The various tests of a group often show a low intercorrelation and are assigned different weights based on an empirical analysis. An ideal group should predict the success of most applicants above a combined critical score and the failure of those below it.

Changes in Function as a Result of Age

Since physical fitness and sensory functions deteriorate with age, a fair estimate of a man's capacities

(*Concluded on page* 257)

Thermal Protection of Lift Motors

By M. G. DIEHL. (From *Polytechnisch Tijdschrift*, Vol. 9, No. 9-10, March 2, 1954, pp. 181a-186a, 9 illustrations.)

IN a study of requirements for the thermal protection of lift motors, it is necessary to consider the dangers to which such motors are exposed and the reactions and effects which may be expected. Limiting the investigation to motors of the three-phase squirrel-cage type, it can be said that damage may occur under the following conditions:—

(1) The motor is switched on while there is an interruption (bad contact, blown fuse, etc.) on one of the lines of the mains supply.
(2) The motor is switched on but, for some reason, cannot start rotating.
(3) The cage is overloaded.
(4) The number of trips of the lift differs considerably from the figure used in the design stage.
(5) The ratio of running time to stopping time is not in accordance with original estimates.

Short-circuiting need not be considered, as it occurs only when the motor is already damaged; a local breakdown of the insulation then permits the flow of an abnormally high current. Cut-out is achieved by means of a protective fuse or a circuit breaker.

In this investigation, it is assumed that the calculations for determining the required capacity of the lift motor have been made carefully, in accordance with users' requirements, so that no inherent danger threatens the motor. The temperature rise in the winding should then not exceed the permitted maximum value. The heat produced by this temperature rise is partly dissipated in the surrounding air, and the remainder raises the temperature of the motor. As a result, the rate of heat dissipation becomes greater and an equilibrium temperature is ultimately reached, when the quantity of heat being generated is equal to that dissipated.

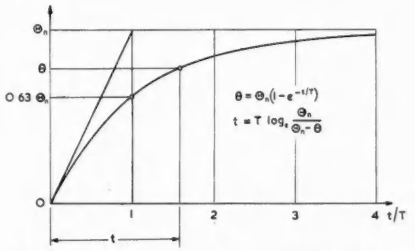


Fig. 1. **Curve of temperature rise plotted against time.**

Fig. 1 shows the relation between rise in temperature and time. The initial slope of the curve is known as the time constant T. The straight line with this slope indicates the time t required to reach various temperatures θ in the theoretical case of no heat losses through cooling. Thus, the time constant T is a characteristic of a machine and its value depends on the mass, specific heat, cooling surface, and cooling coefficient. The exponential curve is valid for a homogeneous body and indicates that the final temperature value Θ_n is very nearly reached after a period of heat generation of from 4 to 5 times the time constant (i.e., when $t/T = 4$ to 5).

The cooling curve is a mirror image of the curve for the temperature rise. Hence, its initial slope is also determined by the time constant. Although the T-values of the motor under working or stationary conditions are not identical, the cooling conditions are also variable, and no advantage will be derived from making the calculations too complicated.

As regards the thermal relay, its heating curve is usually similar to that of the motor. Under normal operating conditions, the temperature of the relay also rises and tends towards a maximum limit. When the motor is overloaded, the temperature rise of the relay is greater and, as a result, the motor is cut out of the circuit when a certain temperature is reached.

The relay and the motor have different time constants, the relay usually having a much smaller mass. It is thus necessary to follow the temperature variations of two different bodies. At first sight it would appear that the relay, having the smaller time constant, should be the first to attain an increased temperature up to some limiting value and should thus cut out the lift motor prematurely. Fortunately, however, actual operating conditions are more favourable.

The relation between overload and cut-out time can be expressed mathematically as

$$t = T_r \log_e [(p^2 - 1)/(p^2 - v_r)],$$

which may be rewritten as

$$(v_r - 1)/(p^2 - 1) = 1 - e^{-t/T_r},$$

where t = time at which cut-out occurs, T_r = time constant of the relay, $p = I/I_n$ = ratio of overload current to normal-load current, and $v_r = \theta/\Theta_n$ = ratio of temperature rise up to cut-out of relay to temperature rise under nominal load.

A similar relation holds for the motor, *viz.*:—

$$(v_m - 1)/(p^2 - 1) = 1 - e^{-t/T_m}$$

where the subscript $_m$ refers to the corresponding values of motor constants. For efficient protection, the cut-out time should be the same in both cases, so that

$$(v_r - 1)/(v_m - 1) = (1 - e^{-t/T_r})/(1 - e^{-t/T_m}) \qquad (1)$$

This equation gives a practical basis for the selection of conditions for adequate protection. For the range of values $t/T < 0{\cdot}1$, the two characteristics coincide and eq. (1) can be simplified to

$$T_r/T_m = (v_m - 1)/(v_r - 1) \qquad .. \qquad (2)$$

which is valid for large overloads. For smaller overloads, the complete formula given in eq. (1) is necessary.

The relation is very easy to apply when v_m approaches unity, i.e., when the temperature at which the motor is to be cut out is only slightly higher than the temperature at nominal load. This is actually the case with modern machines,which are used to their full capacity.

It is important, in this connection, to avoid using too small a value for the relay time constant. Generally, good results are obtainable by means of indirect heating, with a large difference between nominal and cut-out temperature of the relay (i.e., with large v_r-values). Values of $v_r = \theta/\Theta_n$ required for suitable matching of

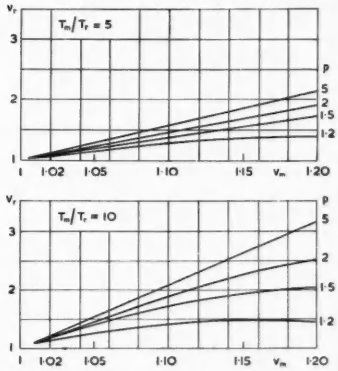


Fig. 2. **Values of v_r required for suitable matching of motor and relay characteristics, as a function of p and v_m.**

motor and relay-characteristics, for different values of $v_m = \theta/\Theta_{n(m)}$, T_m/T_r, and $p = I/I_n$, are given in Fig. 2.

In practice, the conditions are more complicated than those covered by the simple equations given above. The overloading of a lift motor is not only determined by $p = I/I_n$. As the operation of a lift is intermittent, the motor is permitted to operate at a much higher power rating than it would have for steady running conditions. Generally, the operating time is so short that the increased current during starting cannot be dissipated during the running period at nominal speed. Thus, it is necessary to consider the operating frequency and length of trips, i.e., the traffic conditions of the lift, in assessing the required capacity of a lift motor. The operating schedule is used to determine a mean value for the operating temperature of the motor.

It is worth emphasising that satisfactory service cannot be obtained by employing a motor which is too small for the required performance and expecting that the protective relay will take care of excessive temperature rises. The relay is intended for protection in abnormal circumstances and for sufficiently early operation to prevent damage to the motor.

The intermittent operation can be taken into account by introducing the relative running time, defined as

$$x = \frac{a}{a+b} = \frac{\text{running time}}{\text{running time + stopping time}}$$

The complete operating cycle is of the order of, say, 10 minutes. Practical values for relative running time are 15%, 25%, and 40% (i.e., $x = 0{\cdot}15$, $0{\cdot}25$, and $0{\cdot}40$). As shown in Fig. 3, the temperature rises during the

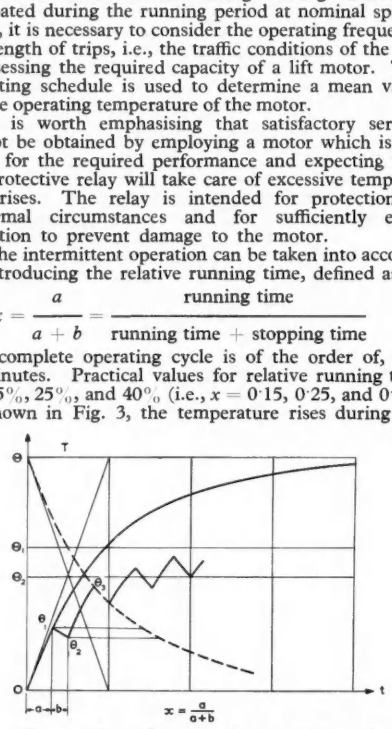


Fig. 3. **Construction of curve of temperature rise for intermittent constant load.**

running time a, and decreases during the stopping time b. After a number of such cycles, the temperature reaches a maximum value Θ_1 and fluctuates thereafter between the values Θ_1 and Θ_2, which are dependent on the time constant T and the value of x.

It can easily be shown that the upper limit is

$$\Theta_1 = \Theta(1 - e^{-xt/T})/(1 - e^{-t/T}) = \Theta F_1 \qquad (3)$$

where Θ is the maximum temperature rise under continuous load (see Fig. 3). If the x-value becomes excessively high, it is necessary to consider the way in which overloading affects the motor or the relay. Let y be the new ratio in such a case; then the upper temperature limit will reach a higher value

$$\Theta_1' = \Theta(1 - e^{-yt/T})/(1 - e^{-t/T}) = \Theta F_1',$$

so that $\Theta_1'/\Theta_1 = (1 - e^{-yt/T})/(1 - e^{-xt/T})$.

After expressing y as a percentage of x for which the motor has been calculated, it is a simple matter to determine Θ_1'/Θ_1 for values of $y = 120\%$ (i.e., $y = 1{\cdot}2\,x$), 150%, and 200%, as well as for different values of t/T regarded as a parameter. The values of Θ_1' can then be expressed in terms of Θ_n, the temperature under nominal load. The results for $x = 0{\cdot}15$ and $x = 0{\cdot}40$ are illustrated in Fig. 4, and show that when the time constant T is small (i.e., when t/T is

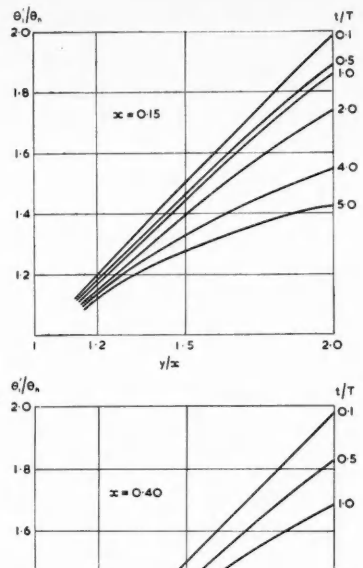


Fig. 4. **Graph showing Θ_1'/Θ_n as a function of y/x, for $x = 0{\cdot}40$ and $0{\cdot}15$.**

large), the temperature rise due to overload is smaller.

The effect of variations in the number of running periods per hour also results in increased motor temperatures, and can be determined by means of eq. (3), which is used to evaluate various values of $F_1 = \Theta_1/\Theta$. These are then plotted against t/T, for different values of x regarded as a parameter (see Fig. 5). As $t = a + b$ = duration of cycle in seconds (see Fig. 3), the number of running periods per hour (or operating frequency) is $f = 3600/t$.

Regarding T as constant, the effect on F_1 of varying the value of the operating frequency f, which is inversely proportional to t, can be seen from Fig. 5. The curves show that changes in f are only of secondary importance for the upper temperature limit. Moreover, in practice, when the operating frequency is increased,

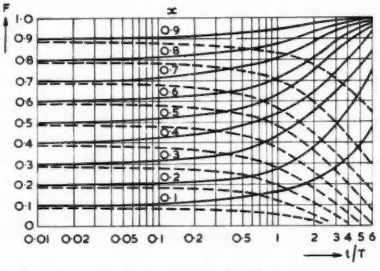


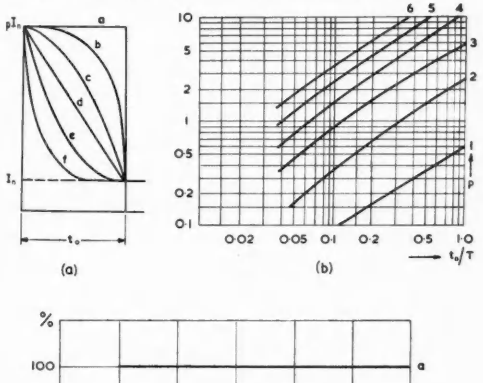
Fig. 5. **Final temperature curves for intermittent constant-load conditions.**

—— $F_1 = \Theta_1/\Theta$; - - - - $F_2 = \Theta_2/\Theta$

although the duration of the cycle is shortened, the running period is not varied appreciably.

The foregoing calculations implicitly assume constant heat generation during the working period. In reality, squirrel-cage motors are subjected to a heavy overload current during starting, normally about 4 to 6 times the nominal value. The variation in this current as a function of time depends on the acceleration of the cage and the motor capacity. To take account of this effect in the present analysis, it is necessary to determine for various characteristic shapes of the current pulse (curves (*a*) to (*f*) in Fig. 6a) the corresponding theoretical values of temperature rise $\theta_1^* = z\theta_1$ (where θ_1^* is the rise in temperature due to starting current, and θ_1 is the corresponding value obtained under the conditions of Fig. 3). The results for curve (*a*) are plotted against t_0/T in Fig. 6b (where t_0 = starting-current duration and T = time constant of motor and relay). If curve (*a*) (rectangular-shaped pulse with constant maximum current) is taken as a basis, and its line of temperature increase is denoted by 100%, it is possible to express as percentages the temperature increases for the other curves, as shown in Fig. 6c, for various values of the ratio $p = I/I_n$. Then, for any motor considered, the variation of the current pulse during starting is determined experimentally and the oscillograph recording is related to one of the characteristic curves (*a*) to (*f*), to determine the effect of additional heat generation. It may be noted that a very high peak, which falls off rapidly as the motor comes up to speed, causes less extra heating than a starting current with a low value of acceleration.

The next step is to estimate for intermittent operation the final temperature rise to be expected after a long period of repeated operating cycles. Provided that the temperature rise during the first cycle does not exceed a certain value, there should be no need for the relay



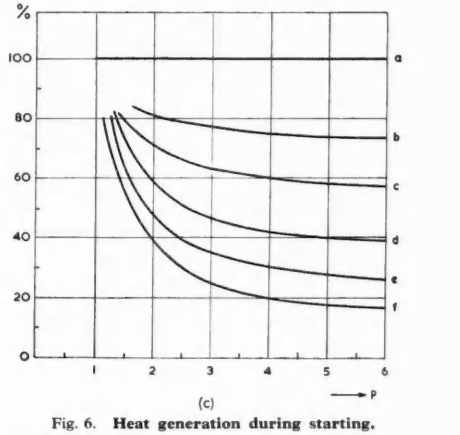


Fig. 6. **Heat generation during starting.**

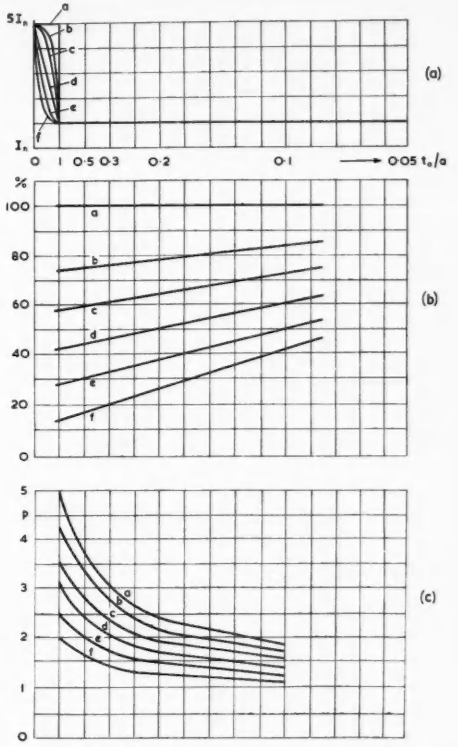


Fig. 7. **Influence of starting current on temperature rise.**

to operate under normal conditions.

In order to obtain a full assessment of the cycle, it is convenient to begin with one of the characteristic curves for the sudden current variation during starting (Fig. 6a). Intermediate values can easily be obtained by interpolation. In a typical case, in Fig. 6a the *a*-curve may be at a value of $p = 5$, and $t_0 = 1{\cdot}0$. As the heat generated is proportional to $I^2 t$, it is necessary to plot against time t (with $t_0 = 1$) the squared values of the curves (*a*) to (*f*) for the starting-current variation. In this case, the a^2-line is at a value of $25\ I_n^2$, etc.

Fig. 7a shows the current variations with the initial current pulses corresponding to the standard curves (*a*) to (*f*) plotted against t_0/a, which is the ratio of the pulse duration to running time in one cycle. For a short trip, t_0/a has a large value (not exceeding unity), whereas longer running times correspond to small t_0/a-values. The temperature rise for the case of curve (*a*) is calculated and used as a reference value of 100%. The heat generated under the conditions related to curves (*b*) to (*f*) is determined and the resulting values are expressed in Fig. 7b as curves indicating the percentages of the *a*-value. Finally, the heat generated can be regarded as being uniformly distributed throughout the running period. It may, therefore, be represented by a constant-load current I, or as an overload factor $p = I/I_n$ in relation to the nominal current I_n. The results of this evaluation are shown in Fig. 7c, which includes the cases with initial current pulses of types (*a*) to (*f*). These curves, also plotted against the t_0/a-ratio, give equivalent p-values, which may be used in conjunction with Fig. 5 to assess whether the temperature limit will be exceeded if the cycle is repeated over a long period.

In this way, the problem has been reduced to that of intermittent operation at constant load. The results

are valid only if the starting process is not so slow as to cause the corresponding temperature rise to be very rapid. In such a case, the running time and the time constant are of the same order of magnitude. This case has never been reported as actually occurring in practice.

A careful analysis of operating conditions does not alter the fact that the lift motor, even with a suitable relay, has a finite life, which is mainly determined by the temperature rise of the motor winding, of which the insulation deteriorates at too high temperatures. From experience, it may be said that the life of a motor is nearly halved for each 10° C above the permitted temperature limit.

Thermal protection offers no possibilities in two cases where the motor is exposed to the greatest risks, i.e., cutting-in when the motor is unable to rotate, and cutting-in with an interruption in one line of the mains supply. Normally, the relay cuts out rapidly when the load current is 4 to 6 times its nominal value, before the temperature becomes excessive. However, the above situations can also occur after the motor has come up to its normal temperature level. It is evident that " slow-acting " relays are then less desirable. Other dangers to be considered are overloading of the cage, excessive operating frequency, and excessive x-values, but these are less important than the two cases first mentioned.

Whether the relay is selected by the lift contractor or by the supplier of the switchgear material, a complete picture of the operating conditions of the lift and the motor is required to achieve the best results. The properties of thermal relays, which are of several types, are determined by the makers for each size and type. Some relays with variable constants have been developed, and these employ indirect heating ; an interchangeable auxiliary mass makes it possible to increase the time constant to suit requirements.

To reduce the unfavourable effect of the starting current on relay temperature, the relay can be connected through a current transformer. At high overloads, owing to the saturation of the iron, the relation between primary and secondary current is no longer linear, so that the starting current contributes only to a slight extent to the heating of the relay.

When there is an interruption in one line of the mains supply, the current through the other two conductors increases, but, if the motor is not at full load, the increase is not sufficient to make the relay operate. However, it is possible to make thermal relays more sensitive for single-phase operation. In special designs, the switching-out characteristic is then shifted to a lower level, such as would be obtained if the nominal current were lowered. This type is of little value for lift motors, because the running period is too short.

SWITZERLAND

Short-Circuit Protective Relay for D.C. Networks

By R. GOULON. (From *Bulletin Oerlikon*, Vol. 33, No. 298, 1953, pp. 40-42, 5 illustrations.)

In direct-current networks, short-circuits can occur in which the current is smaller than the current rating, so that in this case a maximum-current relay adjusted to the current rating does not respond and will not protect the installation. In the following article, a new short-circuit protective relay, developed by the Oerlikon Engineering Company, is described. This relay responds not to the magnitude of the current, but to the steepness of current rise. It also takes account of short-circuits with relatively small rises in current and has a very small time-lag.

IN supply networks fed with direct current, it often happens that, in a network short-circuit, the currents are relatively small and never reach the current rating of the installation. It is, therefore, impossible to deal with these short-circuits with an ordinary overload relay. The short-circuit current can, however, be sufficient to cause considerable damage at its point of origin.

In many quarters the proposal has been made to provide a relay for the determination of the short-circuit which would respond to the current rise caused by the short-circuit. In normal railway service, the large inductance of the field winding of the direct-current series motor does not permit the current to increase rapidly, so that the current rise, which is fixed by the ratio of the ohmic to the inductive resistance of the circuit, is relatively small. In contrast, in short-circuits the motor inductances opposing the current rise are bridged and the current rise becomes correspondingly greater. Moreover, the relay must also have an exceedingly short time-lag, in order to be able to deal with short-circuits in which the absolute current rise is relatively small. For example, in the case of a short-circuit current which rises from zero to 1000 A at the rate of 100,000 A/sec, the time the current would require for this rise is 10 milliseconds ; however, this means that the time-lag of the protective relay must be less than 10 milliseconds.

Fig. 1 shows the basic circuit of a new protective scheme. The transformer (1) is excited by the current in the network and the voltage induced in it is proportional to the rate of change of the current. This voltage is now impressed on the coil of the magnet (2), the trip-armature of which is of small mass and therefore works with a small time-lag. When the voltage induced in the transformer by the change in current reaches the value of response of the magnet, the latter functions and opens the circuit-breaker (3), and the circuit containing the fault is cut out.

As, however, the power of magnet (2) is usually insufficient in itself to break the hold-on current of the direct-current high-speed circuit-breaker (3), another auxiliary relay (not shown in the diagram) is used ; this relay is excited through the hold-on contacts of magnet (5) and breaks the hold-on circuit of the high-speed circuit-breaker (3). It should be noted that this auxiliary relay does not in any way affect the response sensitivity of the protective relay and that, owing to the intrinsic time-lag of the latter, operation of the high-speed circuit-breaker is not appreciably delayed. The variable resistor (4) in the exciting circuit of the magnet serves for adjustment of the limiting value of the current rise above which the relay is to function. According to its setting, the resistor absorbs a part of the voltage induced

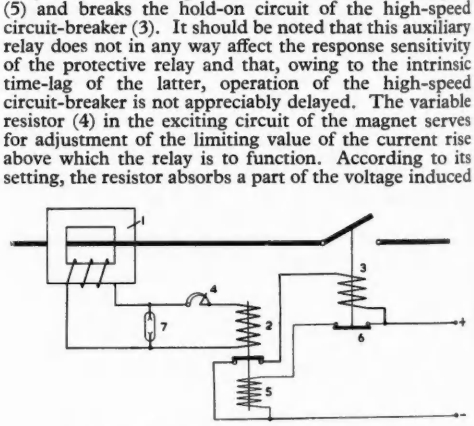


Fig. 1. Basic circuit diagram of the relay.

in the transformer and the magnet receives only the voltage difference. Should the relay also have to deal with a small current rise, little or no resistance should be used, so that the magnet receives the full voltage and responds. If, on the other hand, the relay is to function only for very steep rises, only sufficient resistance should be connected in series, so that, for this limiting value of the current rise, the magnet receives a voltage corresponding exactly to its response voltage. By altering this resistance, the response value of the relay can be set very simply.

Large, i.e., steep, current rises occur not only on short-circuits in the network but also when parts of it are disconnected. With these interruptions the current rise and the resulting induced voltage have a negative sign. So that the relay will not respond to these interruptions, a polarised magnet, which functions only for a certain direction of its exciting current, is used.

When, after a short-circuit, the relay responds and trips the main circuit-breaker, magnet (2), in order to be ready to function again, must be restored to its initial position. This is effected by a restoring coil (5); through the auxiliary contacts (6) on the main circuit-breaker (3), which are closed when the breaker opens, this coil is excited and so automatically restores the magnet.

To avoid overloading the short-circuit relay in the case of very steep rises in current, with consequent large induced voltages, a voltage limiter (7), in the form of a simple surge arrester, is installed in parallel with magnet (2), so that the voltage cannot exceed the response rating of the surge arrester.

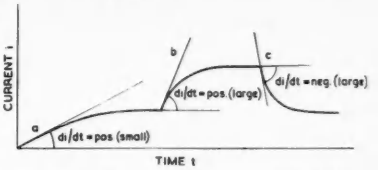


Fig. 2. **Graphs of possible current variations.**

Fig. 2 shows graphs of three possible current variations, in which (*a*) represents a current variation produced under normal electric-traction conditions. A short-circuit to which the relay responds is shown in (*b*), while (*c*) represents breaking of the circuit when this current variation has the opposite sign to that of (*a*) and (*b*).

Measurements with the apparatus have, as expected, given very short response times. The relay operates on a total current rise of 350 A, when the short-circuit current rises at the rate of 25,000 A/sec. Should the rate of rise be 100,000 A/sec, short-circuit protection then operates with a current increase of 500 A, and the response time is only 5 milliseconds.

U. S. A.

Quench Cracks in Wrought-Steel Tubes

By C. WELLS. (From *Metal Progress*, Vol. 65, No. 5, May 1954, pp. 113-121, 8 illustrations.)

This article, which is primarily a review of the work done in the Metals Research Laboratory of the Carnegie Institute of Technology, discusses various aspects of the quench-cracking problem, including the causes of such cracks, and finally outlines possible methods of reducing quench-cracking losses.

A PRELIMINARY study of data on thousands of quench cracks in commercial practices has revealed that (*a*) at least 2% of all tubes contained cracks after being quenched in water, (*b*) cracks of the type shown in Fig.1 were the most common, (*c*) cracking epidemics occurred, (*d*) the cracking problem encountered was statistical in nature, and (*e*) there were large differences of cracking susceptibility among heats having essentially the same chemistry and processed in a well-controlled practice. This behaviour has led to the conclusion that cracking susceptibility is a heat characteristic.

Dimensions of the tubes ranged from 4·5 to 18·0 in. o.d., 1·2 to 7·5 in. i.d., and 80 to 300 in. in length. Compositions were between the following limits:— Carbon 0·25 to 0·5%, manganese 0·6 to 0·8%, chromium 0·6 to 2·2%, nickel 0·7 to 2·4%, molybdenum 0·25 to 0·5%, and vanadium 0·0 to 0·1%.

NATURE OF THE QUENCH-CRACKING PROBLEM

Typical data show that, as mentioned above, cracking susceptibility is a heat characteristic; the occurrence of cracking is epidemic in nature, and the tendency towards cracking varies among tubes from a single heat. Thus, in 44 consecutive heats, 35 heats produced no cracked tubes. These 44 heats were heat-treated in four periods, separated by time intervals in which no heat treating was effected. In the first period, heats No. 1 to 8 inclusive were heat-treated; heats No. 9 to 19 inclusive were heat-treated in the second period; heats 20 to 30 inclusive in the third period, and the remainder in the fourth.

Statistically, this practice is out of control with respect to quench cracks. If the practice had been in control, all tubes for every heat would probably have been free from quench cracks. Statistically, this means that a search for the assignable cause (or causes) of quench cracks in tubes from the above practice appears to have a reasonable chance of success. Since composition (as determined) and heat treatment were essentially constant, both in and out of epidemic periods, it appeared unlikely that the known variation of composition and heat treatment was responsible for quench cracking. This implies that other variables, such as hardenability (ideal diameter D_I) and the beginning of the austenite to martensite transformation (M_S) (which are closely associated with composition) also were not major causes of lack of control. This point of view was further supported by the fact that the plot of D_I or M_S values against the percentage of cracked tubes per heat showed a considerable amount of scatter and the computed correlation coefficient was close to zero.

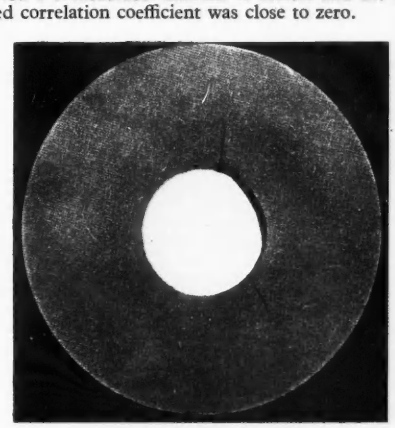


Fig. 1. **Typical quench cracks.**

The quench-cracking problem is therefore statistical in nature, and this suggests that the cracking potential within a forging is best represented by a distribution curve. The shape of the curve is probably not a normal distribution curve but, as a first approximation, it may be considered as such. Actually, there is reason to believe that the distribution of test values which could be obtained and would faithfully represent the variation of cracking potential in a forging consisting of an entire ingot (except for cropped ends) must be shifted in a direction of higher cracking potential values. These higher values would normally be for material taken from positions close to the ingot's " cone of solidification "—the surface where crystals growing from the stool up and from the walls inward intersect. Obviously, stress raisers and regions of weakness in a forging increase cracking potential, and the distribution of these must influence the shape of curve which best represents cracking potential. Tensile stress imposed in the vicinities of high cracking potential will cause quench cracks.

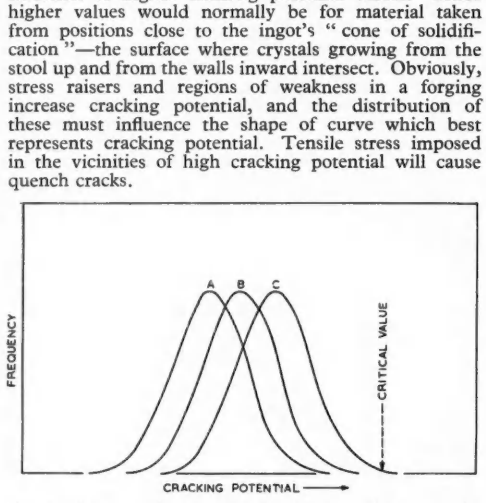


Fig. 2. **Diagram showing statistical nature of the quench-cracking problem.**

When the cracking potential in a tube is equal to or above a certain critical value under a given set of quenching conditions, the tube cracks ; otherwise, it does not. If the average cracking potential were to be increased and the standard deviation (which is a measure of variation) were to remain constant, the statement just made would correspond to conditions in Fig. 2 ; a few cracks would occur in the heat represented by curve *C*, and more cracks could be expected as the location of the probability curve is shifted further over toward the right (the location of the critical value remaining fixed).

Observations that the number of quench cracks per tube varies between zero and a very large number, and the percentage of cracked tubes per heat varies between zero and 100%, are consistent with the viewpoint expressed above regarding the nature of the cracking problem.

Susceptibility Test

Practically all susceptibility tests developed over the last twenty years have at least a limited usefulness in indicating the relative quench cracking susceptibilities of a number of different steels. Conclusions pertaining to the influence of important variables appear to be essentially the same, independent of the test used. The special usefulness of one of these tests[1] is that it may be used to indicate cracking tendency of a part when it is quenched in an oil or molten salt bath.

A special advantage of the cracking susceptibility test for tubes developed at the Carnegie Institute of Technology[2] is that the testpieces, like the commercially quenched tubes (except at the very ends), are radially cooled. Stress patterns in testpieces and tubes are comparable. Standard test discs, $6\frac{1}{2}$ in. o.d., $2\frac{3}{4}$ in. i.d., and $\frac{1}{2}$ in. in length, are notched on the internal diameter, and the minimum notch depth required to cause cracking is an index inversely proportional to cracking susceptibility. The deeper the required notch the less the tendency of the tube to quench crack. When the index of cracking susceptibility was $\frac{1}{4}$ in. or higher, the probability of loss of tubes was low, but the danger of quench cracks in commercially quenched tubes increased rapidly as the index fell below $\frac{1}{4}$ in.

Causes of Quench Cracks

Inter-relationships among factors relating to steelmaking, processing, and heat treatment, are such that the major cause, and quite frequently the major remedy also, will vary from practice to practice.

Pouring Temperature:—A plot of per cent of heats cracked against pouring temperature in the range 2710 to 2890° F indicated that resistance to quench cracking increased with increasing pouring temperature. In the particular practice investigated, no tubes from heats poured at or above 2830° F contained quench cracks. Any heat containing one or more tubes in which quench cracks were present was designated a " cracked heat."

Ingot Size and Forging Reduction:—It is suspected that resistance to quench cracking decreases with increasing ingot size and decreasing forging reduction. Unfortunately, data on which this suspicion is based are few in number, somewhat erratic in nature, and of questionable significance.

Section Size:—As expected, studies revealed that cracking susceptibility increased (cracking-susceptibility index values decreased) as the wall thickness is increased in other words, either the outside diameter of hollow discs was increased (inside diameter being constant) or the inside diameter was decreased (outside diameter constant). It was observed that (*a*) standard discs, $6\frac{1}{2}$ in. o.d., $2\frac{3}{4}$ in. i.d., and $\frac{1}{2}$ in. thick, from certain forgings, had an index of $\frac{3}{16}$ in., (*b*) thicker discs, (3 in.) sometimes cracked if unnotched while others did not, and so had an index close to zero, and (*c*) some commercial tubes, roughly $6\frac{1}{2}$ in. o.d., $2\frac{3}{4}$ in. i.d., and several feet in length from the same heats, cracked and others did not when quenched commercially. Results such as these are believed to indicate that the rate of increase of cracking susceptibility with increasing disc thickness falls off rapidly at first, then more slowly, and finally changes insignificantly with a further increase in thickness. The general agreement between the cracking behaviour of the laboratory-quenched discs, 3 in. thick, cut from tubes in a given heat, and that of commercially quenched tubes from the same heat, suggests that the stress conditions resulting from the radial withdrawal of heat in the laboratory test on discs and the quenching stress conditions in the commercially quenched tubes (away from end effects) are approximately alike.

Surface Defects:—It is known that surface defects of many kinds, including surface flakes, punch marks, scratches, and tool marks, can cause quench cracks. In some instances, surface defects were observed to be a

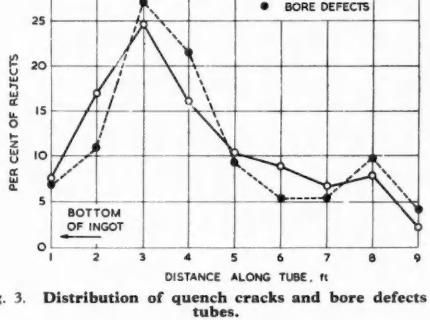


Fig. 3. **Distribution of quench cracks and bore defects in tubes.**

major cause. By rough machining solid forgings before quenching, so as to remove forging laps, forging cracks, and other surface defects, one producer reduced cracking losses practically to zero.

Primary Ingot Structure:—The relatively poor primary ingot structure located in the bottom third of ingots and close to the cone of solidification, together with non-metallic inclusions located in planes of weakness, is believed to constitute a major cause of cracks in many quenched wrought steel products.

An analysis of results supplied by three producers, C, E, and K, revealed that 57% of all quench cracks in C-tubes, 66% in E, and 87% in K were located in steel from the bottom third of ingots. Producer C's seamless tubes were 7·5 in. o.d., 2·5 in. i.d., and 100 in. in length; E's forgings were 11 in. o.d., 3 in. i.d., and 200 in. in length, and K's forgings were 17·5 in. o.d., 7·5 in. i.d., and 300 in. in length. The position of the cracks in 89 C-tubes coming from the bottom third of ingots is shown by open circles in Fig. 3. Their maximum frequency occurred in material located between 25 and 36 in. from the end of tubes, i.e., in a position in ingots corresponding closely to the apex of the cone of solidification.

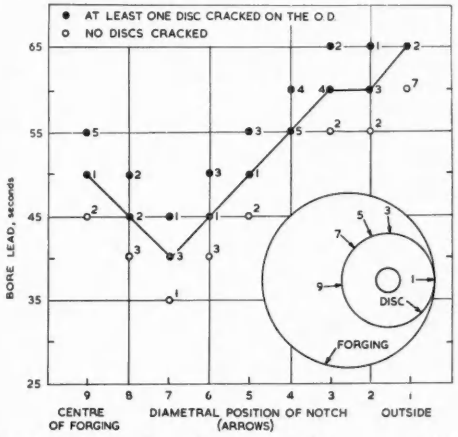


Fig. 4. **Variation of cracking susceptibility across a radius in a large forging.**
The number of each plotted point signifies the total number of experiments.

The variation of cracking susceptibility across a radius in a large forging, 18·5 in. o.d., 7·5 in. i.d., and 210 in. in length, made from a 34-in. square ingot, was lower toward the outside of the forging, as indicated by longer " bore-lead " time (Fig. 4). Standard discs, notched on the outside to a depth of $1\frac{3}{8}$ in., were quenched with water—first on the bore for a time (designated the " bore-lead " time) and then on both outside and inside diameters simultaneously. The relation of notch to disc, and of disc to forging is indicated in the figure. Material in the vicinity of the notch, position (9), was located a little below the top discard of the original ingot and about 2·5 in. from the centre of the forging; the material in position (1) was located about 9 in. from the centre and was close to the outside of the forging.

Bore Defects:—A comparison of the two curves in Fig. 3 shows them to be essentially alike, and suggests that a major cause of both quench cracks and bore defects is the presence, in the weaker part of the primary ingot structure, of discontinuous stringers of hard angular particles of alumina-rich non-metallic inclusions. " Bore defects " are wall ruptures in pierced tubes observed in macro-etched sections, or during visual examination of the inner surface of the tubes.

It has never been proved conclusively that quench cracks or bore defects would, or would not, have been present in the pierced tubes if detrimental non-metallic inclusions had been absent. This author's present opinion is that, in the absence of such inclusions, the ingot structure, even in the vicinity of the cone of solidification, would have successfully resisted the formation of bore defects during piercing, and cracks during quenching.

Bore defects are obviously stress-raisers and no doubt intensify the cracking problem; however, they are not necessarily present in quench-cracked material. Many forgings which contained quench cracks and came from several producers appeared to be practically free from damaging non-metallic inclusions and bore defects.

Out of about 13,000 seamless tubes from the 44 basic open-hearth heats already mentioned, about 450 (3·5%) had quench cracks in them; out of approximately 50 basic electric heats, none contained quench cracks. Bore defects were also practically absent in the basic electric material. Whether the primary ingot structure of basic electric steel, especially in the region of the cone of solidification, was stronger because of a drastic reduction of detrimental inclusions (or for some other reason) is still open to question. While, in this particular instance and steel plant, a change from basic open-hearth to basic electric steel eliminated both quench cracking and bore defects, many basic electric steel forgings, including both tubes and solids supplied by several companies, were known to contain quench cracks.

As the bottom portion of steel ingots produced in standard cast-iron moulds is inherently less able to resist and to dissipate imposed combined stresses than is the balance of the ingot, it has been suggested that the ingots be cooled more slowly through the bottom or stool, so that the cone of solidification be lowered into the bottom crop and discarded.

Gas Content:—Of the gases dissolved in steel, hydrogen is suspected to be the most damaging. For many years hydrogen segregation and thermal and transformation stresses have been thought responsible for " flakes," which, as they themselves are cracks and obviously stress raisers, can be a major cause of quench cracks. A typical distribution of quench cracks in 107 flaked tubes shows that material located between 157 and 168 in. from the end (about 15 in. below the top discard of the 34-in. square ingot) quench-cracked most frequently. Practically no cracks occurred in portions of forgings consisting of steel from the bottom third of ingots where, in unflaked tubes, the occurrence of quench cracks is usually at a maximum.

Carbon Content:—Investigators agree that carbon lowers the austenite-martensite temperature (M_s) more effectively than any of the common alloying elements, and because of a larger volume change in cooler, more rigid steel, increases cracking susceptibility most drastically. Data given in Fig. 5 show for each of two practices (*a*) the relation between carbon content and the percentage of heats cracked and (*b*) the safe limit of carbon content below which the probability of cracking is so low as to be insignificant from an engineering point of view. The regression lines intersect the x-axis at 0·26% and 0·35% C respectively. As expected, no tubes with 0·26% C or less cracked when quenched to martensite and no tubes with 0·35% C cracked when quenched to a mixture of martensite and bainite.

As the degree of slack-quenching increases, i.e., the proportionate amount of bainite increases in the heat treated microstructure, the volume change associated with the decomposition of austenite decreases and the redistribution and relief of stress through plastic flow become easier. It is not surprising, therefore, that higher carbon content can be tolerated in the slack-quenched steels.

There is reason to believe that the detrimental

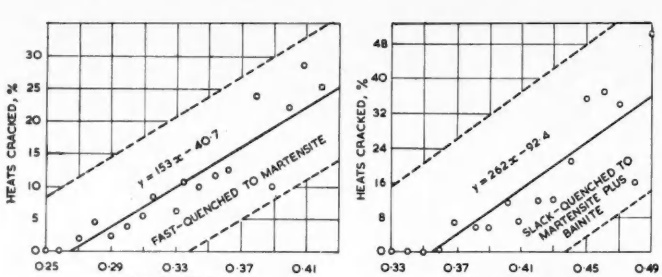


Fig. 5. **Relation between microstructure and quench cracks in large forged tubes.**
(*a*) 2384 heats. Type: 1% Cr, 2% Ni, 0·4% Mo, 0·7% Mn. 7·5 to 11·0 in. o.d., 2·5 to 3·5 in. i.d., 100 to 200 in. in length.
(*b*) 1310 heats. Type: 1% Cr, 0·4% Mo, 0·1% V, 0·7% Mn. 13·5 to 18·0 in. o.d., 5·5 to 7·5 in. i.d., 150 to 200 in. in length.

effect of carbon on cracking susceptibility results primarily from its influence on the transformation temperature.

Hardenability:—Insofar as increased hardenability is usually accompanied by a lowering of M_s, there has been a tendency to conclude that increased hardenability means increased cracking susceptibility. Actually, if M_s is not changed, hardenability may be raised considerably without affecting the cracking susceptibility of steels quenched to martensite. Data gathered from several sources have confirmed this point of view.

Boron has no appreciable effect on cracking susceptibility, because it scarcely affects M_s at all, but it does increase hardenability quite markedly.

Surface Decarburisation:—It is possible that surface decarburisation has an effect on cracking susceptibility in engineering constructional steels containing 0·25 to 0·50% C; some metallurgists are of the opinion that decarburisation is beneficial, while others believe it to be harmful.

Alloying Elements:—The effect of normal variation in alloy content, heat to heat, for a given grade of steel appears to be relatively insignificant.

The effects on M_s of each per cent of the usual elements have been tabulated[3]. Carbon lowers M_s most drastically, then manganese, and so on. Aluminium actually increases M_s. These data suggest that a given addition of carbon should raise cracking susceptibility more than would a comparable addition of manganese; manganese should raise it more than would a comparable addition of vanadium, and so on.

Uniformity of Quench:—Results have been obtained which show that quenching technique may have an important bearing. In one practice, several tubes, each 7·5 in. o.d., 2·5 in. i.d., and 110 in. in length, were quenched at one time. They were hung vertically and arranged in a circle, so that certain tubes had two neighbours, one on each side; others had a neighbour on one side only, while still others had no neighbours. Tubes with no neighbours were found to be the most uniformly quenched and cracked the least frequently; tubes having one neighbour only were the least uniformly quenched and cracked most frequently.

Austenitising Temperature:—Increasing the austenitising temperature tended to increase cracking susceptibility. The determined index of cracking-susceptibility. value was, on the average, about $\frac{1}{4}$ in. for standard discs austenitised for one hour at 1525° F and quenched; it was $\frac{3}{16}$ in., on the average, for comparable discs austenitised for one hour at 1680° F and quenched.

Temperature of Quench:—A plot of the percentage of heats cracked against finish temperature in the range between 100 and 500° F showed that the probability of occurrence of quench cracks would decrease with increasing finish temperature. This observation has been confirmed in the laboratory, since index of cracking susceptibility values are somewhat higher (cracking susceptibility lower) for discs quenched to 350 to 500° F than for discs quenched to 60° F.

Elapsed Time Between Quench and Temper:—In order to reduce the well-known danger of cracking between quench and temper, quenched tubes, while still warm, should be promptly transferred to the tempering furnace.

Normalising:—Normalising before austenitising tended to decrease quench cracking susceptibility. Standard discs consisting of normalised material subsequently austenitised and quenched had a slightly higher index (lower cracking susceptibility) than comparable discs similarly heat-treated but not normalised.

Remedies

Many remedies which would be expected to reduce quench-cracking losses are self-evident from the information given above. Some of the more important remedies already successfully applied include (*a*) prebore quenching of tubes, (*b*) a change from basic open-hearth to basic electric steel, and (*c*) rough machining before heat-treatment.

Laboratory results and the limited experience of at least one producer of large tubes have demonstrated that pre-bore quenching, where applicable and properly carried out, is very effective. This consists of quenching the bore initially for a certain time, followed by a simultaneous quench of the bore and outside surfaces. A pre-bore quench of about 10% of the total quenching time is tentatively recommended.

The best remedy for certain cracking problems may in some instances involve a drastic change of composition. A composition along the lines suggested by Jaffe and Hollomon[3] should then be designed, providing the resulting analysis is not too costly for use in the given application and does not contain more strategic alloying elements than would normally be permitted for such a purpose. In "designing" the composition of a steel for more than one application, many problems (including quench cracking) must be faced, and the final decision usually results in some compromise. This should be kept in mind by those who would recommend "ideal compositions" to prevent quench cracking. To avoid quench cracks, the newly designed steel should have carbon on the low side, a higher M_s, a "balanced" alloy composition to ensure more than the minimum of hardenability and resistance to tempering, and mechanical properties needed to meet specification requirements and to perform satisfactorily in service.

Since control chart studies showed that practically all quench cracks occurred in tubes from heats which were "out of control" (in the control-chart sense) with respect of cracking susceptibility, and that variation in composition did not appear to be one of the assignable causes of lack of control, it will usually be more logical to try other remedies than a new steel analysis. As already mentioned, one successful remedy (involving a change of "heat characteristic," known to be closely associated with the cracking problem) was a change from basic open-hearth to basic electric steel.

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(1) Chapman and Jominy: *Metal Progress*, Sept. 1953, p. 67.
(2) *Transactions, Amer. Soc. Met.*, Vol. 42, 1950, p. 206.
(3) Jaffe and Holomon: *Transactions, Amer. Inst. Min. and Metall. Eng.*, Vol. 167, 1946, p. 618.

Reciprocal or Pendulum Milling

By R. DIES. (From *Werkstatt und Betrieb*, Vol. 87, No. 4, April 1954, pp. 157-160, 9 illustrations.)

IN the mass production of many light-alloy components, considerable use has been made of rotary-table milling machines, the operating principles of which are well known. These machines are generally considered to be of advanced design, and they are, in fact, capable of high production rates. It has, however, been established that they have certain shortcomings which cannot be overlooked. Components frequently have to be machined to very close limits and must have a good surface finish; these requirements cannot always be met, owing to the circular feed movement of these machines. Furthermore, the rigidity of the whole machine cannot compare with that usually associated with normal milling machines. Finally, simultaneous roughing and finishing on one machine using two spindles is not recommended, and consequently other solutions have to be found.

A full appreciation of the above limitations has led to the development of a milling machine which does not have these shortcomings and at the same time permits extremely efficient machining. It is known as the reciprocal or pendulum milling machine, the operating principle of which is ideally suitable for strict accuracy and surface-finish requirements and in this respect achieves results far superior to those from a machine of the rotary-table type.

In reciprocal milling, the machine table performs a continuous reciprocal or pendulum motion at the machining feed rate, the movement being limited at the left and right extreme positions by adjustable end stops. The milling cutter does not pass over or clear the last component (Fig. 1). This may seem to conflict with normal practice; it was found, however, that the cutter, which passes over the work during roughing, removes some additional metal during the return or finishing pass. A considerable time saving can therefore be effected by reducing the stroke of the table. The sequence of operations is then as follows:—Components on the right-hand side of the table are machined during the table movement to the left; other components are simultaneously loaded and unloaded on the left-hand side of the table. The reverse applies during the table movement to the right.

The reciprocal milling machine is in most cases used for the first machining operation on the component. It is therefore essential to make provision for a heavy roughing cut. One roughing cut, however, cannot achieve the geometrical accuracy and high finish required for a mating or a locating face for subsequent operations. Consequently, a finishing cut is taken during the return stroke of the table, following the roughing operation performed on the forward stroke. The behaviour of the machine and material makes it essential for the finishing operation to be performed under constant clamping pressure and constant depth of cut. Most materials have a tendency to compress under the cutting pressure and to spring up or expand again immediately after the cutter has passed over them. This behaviour can well be illustrated by "sparking out" when grinding, and is exploited in the operation of the reciprocal milling machine.

Determination of the extent of this compression and expansion of materials during a roughing cut was the subject of a series of thorough tests. It became clear that metal removal during the finishing cut, i.e., during the return stroke following the roughing operation, varied according to the shape of the workpiece. For a light-alloy material it ranged from 0·00016 in. to 0·00032 in. The most important conclusion, however, was the fact that the finishing cut was completely unaffected by the depth of the roughing cut. Tests in which roughing cut depths were varied from 0·008 in. to 0·16 in. showed that metal removal during the subsequent finishing operation remained constant within the above-mentioned limits.

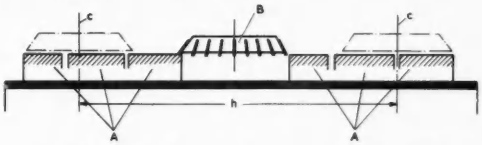

Fig. 1. **Schematic diagram of the reciprocal-milling method.**
A = Components; *B* = cutter; *c* = limits of cutter travel; *h* = table travel.

The reciprocal milling machine was originally developed for the machining of light alloys. It can also be used for similar materials by altering the cutter speed. The machine is of exceptionally strong and rigid construction, which permits a cutter of approximately 16 in. in diameter to rotate at 1000 rpm, giving a cutting speed of about 4200 fpm with negligible vibration. A large number of fixtures can be accommodated on the table, which is approximately 5½ ft in length, and its surface can be utilised much more efficiently than that of a rotary table. On the latter, components must be set up radially, or because of limitations of table and cutter diameter, end to end; both alternatives are wasteful, insofar as area and cutter travel are concerned. The table of the reciprocal milling machine offers the possibility of setting up components much more closely together. This point can be illustrated by considering as an example a motor-cycle engine crankcase, in which several faces have to be machined. The complete set for one crankcase consists of four components, with six machined faces, i.e., (1) to (6) in Fig. 2. Two of the components are machined on two sides, whereas the other two are machined on one side

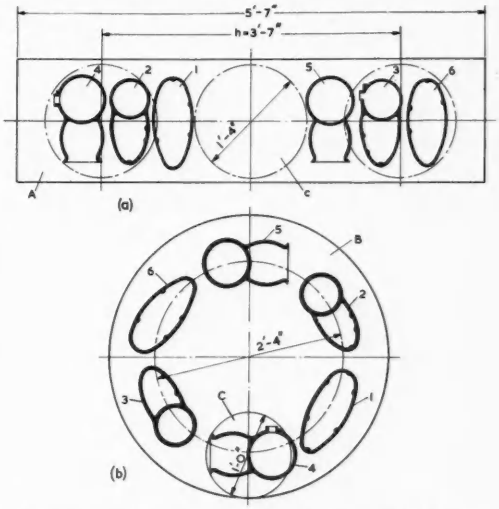

Fig. 2. **Disposition of components on (*a*) a reciprocal milling machine and (*b*) a rotary-table milling machine.**
(1)-(6) Machined faces of components.
A = Table of reciprocal milling machine.
B = Table of rotary milling machine.
C = Cutter.
h = Travel of reciprocal milling machine.

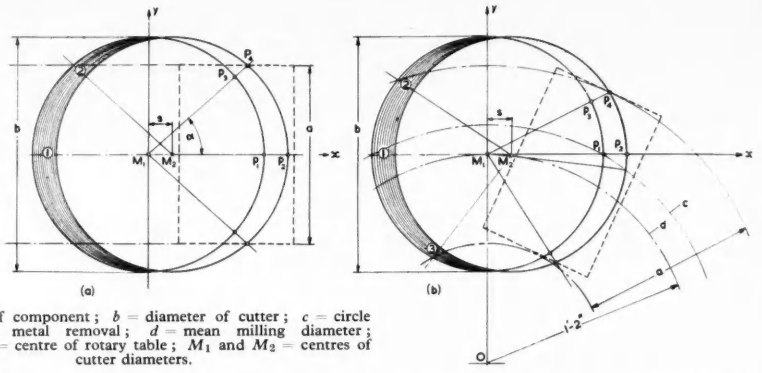

Fig. 4. **Schematic illustration of the geometrical analysis of (*a*) reciprocal milling and (*b*) rotary-table milling.**

a = Length of component; b = diameter of cutter; c = circle of maximum metal removal; d = mean milling diameter; s = feed; O = centre of rotary table; M_1 and M_2 = centres of cutter diameters.

only. Fig. 2(a) shows how two sets can be accommodated on the reciprocal milling machine, while Fig. 2(b) shows the same two sets mounted on the table of a rotary-table milling machine. The crankcases in both instances are arranged so that each machine cycle produces one complete set of component parts.

The central part of the table of a reciprocal milling machine is not used for components to the extent of the cutter diameter. This is intentional, to avoid the influence of the finishing operation in progress on one half of the table by the roughing operation on the other half of the table. The improvement in surface finish occasioned by this simple measure is very considerable. Finish requirements on some components are not very high, and in such cases it is quite possible to utilise the central portion of the table. The output of the machine can thus be greatly increased.

In the case of a rotary milling machine, the components must be arranged tangentially on the table, and although it is true that here again a complete set of components for one housing can be produced in one cycle of the machine, it is virtually impossible, however, to compare the production times of the two methods, as their relative efficiency will depend on the type and shape of the component in question. It would probably be found that each method will prove superior for certain components.

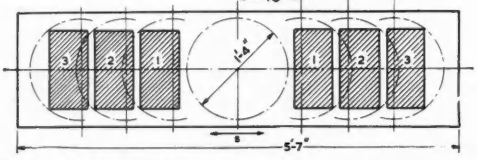

Fig. 3. **Machining of two, four, or six identical components on a reciprocal milling machine, using variable table travel.** s = table feed, ipm.

Should the design of the crankcase be modified to require only five or less machined faces, the change would be reflected in shorter times on the reciprocal machine, as the stroke of the table can be reduced accordingly. This is not possible on the rotary machine, because the table must always complete one full revolution, irrespective of the number of components. Furthermore, with the reciprocal machine, it is possible to machine one component only.

Quantity production of one type of component is naturally quite frequent and the most economical production method for this type of work is of great importance. It is quite possible to machine a number of identical components at one setting on both types of machine. Assuming that six components are to be machined at one setting, the time per component on the reciprocal machine would be 1 min, whereas on the rotary-table machine it would be 0·92 min. If, however, the stroke of the reciprocal machine is reduced to deal with only four or two components (Fig. 3), the times per component become 1·06 and 1·25 min respectively. This shows that the saving in time obtained by the use of a large number of fixtures decreases rapidly. The saving in time between machining six and four components is only 0·06 min. If the price of a fixture is taken to be £125, it would take some 3½ years to amortise the two fixtures on this basis.

The above example shows that in this case, when four fixtures are used, the time per piece on the reciprocal machine, i.e., 1·06 min, is longer than on the rotary-table machine. The overall efficiency, even in this case, would, however, be higher with the reciprocal machine, because of the smaller number of fixtures required and because of the much lower initial cost of the machine.

Due to their nature, the crankcases of two-stroke engines are always subjected to a certain pressure. The surfaces muct therefore be machined in such a way that the assembled unit is completely proof against oil leakage, and this of course entails high surface finish. Economical production of such surfaces is possible only if it involves a minimum of stages or passes. On the reciprocal milling machine they are produced in one cycle of the machine, whereas, when rotary-table machines are used, one pass is generally required for roughing and another for finishing. Owing to the inferior accuracy of the rotary-table machine, it is also frequently essential to lap the surfaces as a final operation, as only then can a surface of the required quality be obtained. Two-spindle rotary-table machines cannot be recommended for this type of work, because of the inferior finish they inevitably produce.

A brief analysis of geometrical considerations involved in reciprocal and rotary-table milling should be of interest. These are illustrated for both processes in Fig. 4; the component, table feed, and cutting speed are identical in both cases and the effective feed for the rotary table is taken to be the value acting at the centre of the component. Since the ratio of feed to cutting speed is 1/2600 in this case, the path of the cutter can be taken as a circle without affecting the accuracy of the analysis. Some of these circular paths are shown in the illustrations for both processes.

The surface finish is to a great extent determined by the size and uniformity of chip formation, and a comparison of the latter is therefore important. For such a comparison, it is necessary to determine the number of cutter passes over a unit area near the centre and near both extremes of the component, as shown schematically in the left co-ordinate half of the diagrams in Fig. 4. Taking the number of cutter passes over the centre of

the reciprocal-milled component as 100%, the following values have been obtained for the other points :

Reciprocal Milling:— Area (1), 100%; area (2), 126·9%.

Rotary-Table Milling:— Area (1), 103·85%; area (2), 119·25%; area (3), 165·4%.

These values were determined graphically; they can be compared with values for extreme points of the component, determined by calculation. The calculation for the reciprocal-milling process is illustrated in the right co-ordinate half of Fig. 4(a). M_1 and M_2 represent the centre of the cutter, displaced by the feeds; this is also shown by points P_1 and P_2. The chip thickness near the extreme point of the component is represented by P_3P_4, and its value can be calculated as follows :—

Equation of cutter periphery circle about M_1 :

$$x^2 + y^2 = r^2$$

Equation of cutter periphery circle about M_2 :

$$(x - s)^2 + y^2 = r^2$$

Equation of path P_3P_4 :

$$y = x \tan \alpha$$

Hence, $$P_3P_4 = \sqrt{(x_4 - x_3)^2 + (y_4 - y_3)^2}$$

Assuming that $r = 0{\cdot}79$ in., $s = 0{\cdot}034$ in., and $\alpha = 40$ deg., $P_3P_4 = 0{\cdot}028$ in.

The chip thickness at this point of the component is therefore about 71% of the maximum chip thickness in the centre of the component. Agreement with values obtained graphically is satisfactory, bearing in mind the fact that in the graphical method a unit area is used, whereas the calculation involves a distance or path. Similar calculations were made for rotary-table milling and the results of these also showed adequate agreement with values obtained graphically.

The point of maximum chip thickness in rotary-table milling is not in the centre of the component. It is displaced by amounts depending on the cutter diameter. This fact, arrived at by purely geometrical considerations, is illustrated in Fig. 5, which shows quite clearly the advantages of reciprocal milling over rotary-table milling, insofar as the uniformity of the milled surface is concerned. Fig. 5(a) shows a chip-thickness diagram for normal reciprocal milling, while three possible alternatives with rotary-table milling are given in Figs. 5(b), 5(c), and 5(d). Fig. 5(b) shows the normal case, where the centre of the component lies under the centre of the cutter. More favourable results—Fig. 5(c)—are obtained by moving the component outwards, within the limit of the cutter diameter, but even then complete uniformity cannot be achieved. The most unfavourable results—Fig. 5(d)—are obtained by moving the component towards the centre of the table, and this arrangement should never be used in practice.

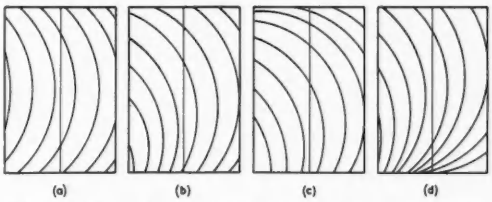

Fig. 5. **Schematic representation of milling patterns in reciprocal and rotary-table milling.**
(*a*) Normal reciprocal milling; (*b*) normal rotary-table milling; centre of component under centre of cutter; (*c*) rotary-table milling; component as near as possible to the periphery; (*d*) rotary- table milling; component as near as possible to the centre of the table.

The advantages of reciprocal milling would be further enhanced by using a cutter with a larger diameter. This is quite feasible, owing to the very rigid construction of the machine. This is not, however, possible with the rotary-table machine, where the cutter diameters are generally smaller, owing to limitations imposed by the construction of the machine. The unevenness of the cut, as a result of varying distances from the table centre, can be minimised to a certain extent by positioning the components with their longer axis in the direction of feed. However, this automatically entails longer cutting times.

Initial capital outlay is a most important factor when considering the relative economy of the two processes. In this respect the reciprocal milling machine is again greatly superior. Its cost is well below that of a single-spindle rotary-table machine, and consequently bears no comparison with the cost of a two-spindle rotary-table machine. A further important consideration in many factories is limitation of floor space, and here again the superiority of the reciprocal milling machine over the rotary-table milling machine is quite definite.

SWITZERLAND

Reduction of Oil-Ash Deposition in Gas-Turbine Plants

By P. T. SULZER. (From *Schweizer Archiv*, Vol. 20, No. 2, February, 1954, pp. 33-41, 9 illustrations).

In our March, 1954, issue, we published an article on slag deposition and corrosion in gas-turbine plants, describing the difficulties occurring in the high-temperature operation of such plants and considering possible solutions to the problem of slag corrosion due to ashes in fuel oil. In the following article, indications are given of a method of reducing oil-ash deposition by means of controlled combustion.

OIL-ASH deposition, due to the use of heavy oils, is the cause of fouling and corrosion of turbine blades, combustion chambers, etc. The most dangerous components are vanadium and sodium compounds, which occur with other mineral substances in the form of a fairly viscous mass. Vanadium pentoxide has a catalytic effect in that it brings the highly soluble metal oxides into contact with the structural steels and thus causes corrosion.

Practical experience with heavy oils has led to contradictory results, the use of a certain oil having given rise to difficulties in some cases, but not in others. This indicates that the important factors to consider are not only the chemical composition of heavy oils but also the operating processes and design of the plants. The fact that controlled, i.e., incomplete, combustion can be employed to solve fouling problems was first indicated by Bowden.

Incomplete combustion can be achieved in various ways, i.e., by (1) good air mixing, but with insufficient air, (2) insufficient mixing with excess air, (3) excessive air flow in the flame zone, with good mixing to prevent attainment of the required temperature for complete

combustion, and (4) coarse atomisation. Smoke and fine soot (particles of approximately 0·05 micron), as well as spherical coke particles (5 to 50 microns) occur under conditions (1) and (2), but smoke and soot are generally absent with (3) or (4).

The critical oil-droplet diameter for complete combustion varies for each combustion chamber and each operating condition. It depends on the fuel used and the time of exposure to an infinite excess of air at a certain temperature. Combustion proceeds in the following stages :—Distillation and evaporation of constituents with a low boiling point ; chemical breakdown of the higher hydrocarbons ; and combustion of the resulting spheroidal carbon skeletons. The ash-forming substances have a fairly low vapour pressure and consequently concentrate on the residual spheroidal carbon particles. Under complete combustion, these reach diameters of between 5 and 50 microns and adhere to the turbine blades, etc. after impact. Condensation of NaOH and V_2O_5 is also a possible consideration.

Bowden stated that, in incomplete combustion, the residual carbon skeleton prevents the adhesion of the ash contained in it, and that the growth of depositions is impeded by showers of light coke particles on the blades. Tests at C. A. Parsons & Co. Ltd., Newcastle, substantiated these statements. Coarser atomisation and incomplete combustion increased the mean droplet diameter from 42 to 77 microns and prevented extensive ash deposition.

Laboratory tests at the Sulzer works in Switzerland have further shown that, as an alternative to using coarser atomisation, an increase in air delivery in the primary zone of combustion lowers the mean combustion temperature and also produces the desired effect. Bowden's explanation appears incomplete, because it neglects the chemical reactions of the ash components, which can be summarised as follows :—

(a) Primary reactions of the ash components in the flame zone. Owing to the high temperatures (above 1500° C), all the sulphate-forming processes are eliminated and it is probable that the oxides form compounds among themselves.

(b) Secondary reactions between 1400° and 700° C, during entrainment in the gas flow to places where deposits are formed. These reactions occur mainly between ash components in vapour form and SO_2 or SO_3. Chemical equilibria are not attained owing to the high flow velocities and temperature gradients. Turbulence may also be an important factor.

(c) Tertiary reactions at deposition centres, particularly between the deposits and the metal, or between the deposits and SO_2 or SO_3 (or CO_2, if little SO_2 is present).

Vanadium compounds : V_2O_5 is stable below 1200° C. Sulzer laboratory tests explain its corrosive action as follows :—Above 650° C, liquid V_2O_5, with a high wetting capacity first dissolves the protective oxide film on the steel and transmits some of its oxygen to the metal beneath it. Mixed phases of V_2O_5 and V_2O_4 (and occasionally V_2O_3), with variable partial pressures of oxygen, favour this process. The lower vanadium oxides and the corrosion products dissolve in the excess V_2O_5, diffuse towards the oxygen, and oxidise again to V_2O_5. The corrosive process slows down only with increasing concentration of non-vanadium oxides, which raise the viscosity of the wetting mixture and thus prevent the flow of the lower vanadium oxides with high melting points towards the oxygen. Sulzer observations indicate that electro-chemical phenomena (pitting, etc.) have no important part in this process. The Sulzer tests have shown that vanadium oxides in the presence of carbon, and hence inside or on the surface of carbon particles, cannot form any liquid phase below the melting point of the lower oxides V_2O_3 and V_2O_4, which would be essential for the occurrence of depositions and corrosion.

Sodium compounds : The sodium compounds still contained in the carbon skeleton during combustion are either thermally stable NaCl or NaOH (and possibly Na_2O) produced by reduction with carbon from Na_2SO_4. Both have a considerable vapour pressure, and volatilisation from the highly heated carbon particles is quite possible. Outside the reducing atmosphere, these substances in the gaseous phase react with SO_2 and O_2 exothermically and produce Na_2SO_4. The latter, having a low vapour pressure, will deposit as very small particles in the solid phase. This explains why, in gas turbines, where SO_3 is present, sodium-containing compounds occur only as sulphates and never as chlorides. Direct fouling by primary condensation of NaCl or NaOH at the place of deposition and the formation of Na_2SO_4 through secondary sulphate formation are improbable.

Thus, incomplete combustion will hardly prevent the occurrence of Na_2SO_4 depositions, and this has been proved by Bowden and others in practical tests. Sulzer tests show that lower vanadium oxides with NaOH in a reducing atmosphere form compounds with a fairly high melting point, these compounds volatilising with difficulty. From this it is concluded that, in the incomplete combustion of sodium-containing oils, the simultaneous presence of vanadium tends to prevent the formation of ash depositions.

Alkaline-earth compounds : With complete combustion, the alkaline-earth metals (represented mainly by calcium) promote the development of hard deposits through sulphate formation. This fact is in apparent contradiction with the high melting point of $CaSO_4$ (1450° C).

When calcium is present, the ash particles suspended in the burnt gas contain CaO which, unlike NaOH (or Na_2O or NaCl), does not evaporate at the temperatures in question. Sulzer tests have shown that free SO_3 is necessary for the formation of $CaSO_4$ from the oxide. This SO_3, however, occurs in sufficient concentration only below 900° C. From gas-kinetic considerations, it can be said that a transformation between fairly large-size CaO particles and SO_3 is improbable in the concentrations occurring. This leads to the conclusion that sulphate formation takes place in a tertiary reaction at the place of deposition between the loosely adhering CaO and V_2O_5, as well as with the burnt gases. The heat released in this reaction is capable of heating the sulphate thus obtained to well above the surrounding temperature. The softened surface obtained in this process facilitates the adhesion of further free ash, and this finally leads to the development of hard crusts. The other alkaline-earth metals behave in a similar manner, but are less troublesome, owing to the temperature resistance of their sulphates. In a reducing atmosphere, no sulphates are stable at these temperatures inside or on the surface of soot particles. The presence of alkaline-earth metals, which occur only as oxides with a very high melting point, improves the effectiveness of incomplete combustion.

Corrosion in incomplete combustion : Little is known at present on this subject. From the above, it follows that the presence of carbon prevents the typical corrosion produced by V_2O_5. However, this pre-supposes that there is constantly good contact between carbon and ash, and hence that uniform atomisation of the fuel is maintained. With a non-uniform size distribution of the droplets, part of the fuel will generally be burnt completely and will form free ash. This results in depositions, in which the V_2O_5, sulphates, and released oxides react locally with soot. Contraction of the deposits occurs, causing the tinder to flake off continuously, together with the deposits adhering to it. In experiments at the Sulzer works, using atomisers with an unfavourable characteristic, it was found that the corrosion thus produced is much more extensive than in the case of an undisturbed development of the depositions. These give a certain amount of protection to the steel after saturation with the released oxides.

The Automatic Measurement of Specific Heat

By T. HIRONE, S. MAEDA, I. TSUBOKAWA, and N. TSUYA. (From *The Science Reports of the Research Institutes, Tôhoku University*, Series A, Vol. 5, No. 6, December 1953, pp. 513-519, 7 illustrations.)

In this article, a method of measuring and recording automatically the specific heat of alloys and compounds is described. By means of this apparatus, which has been used successfully for the thermal analysis of various ferromagnetic compounds and binary superlattice alloys, it is claimed that the lengthy and tedious work involved in such analyses can be avoided, without, however, sacrificing accuracy of measurement.

NUMEROUS methods for measuring the specific heat of alloys or compounds, together with their temperature dependence, have been reported. According to their principles of measurement, these may be classified into two types, i.e., adiabatic and conduction methods, respectively. The method of Sykes[1] belongs to the former type, while that of Smith[2] belongs to the latter. These methods have been employed satisfactorily, according to the character of the temperature dependence of the specific heat, as well as the other thermal properties of the substances investigated. For the measurement of specific heat, it is claimed that uniformity of temperature in the specimen is essential. For this reason, heating of the substance cannot be effected too rapidly; hence, in general, thermal analysis takes a long time.

The apparatus for measuring specific heat described below belongs to a kind of adiabatic type proposed by Sykes. In this method, the specimen material is packed into a container, with a heating element kept free from radiation. The impressed energy in the heating element during a unit rise in temperature gives the specific heat of the specimen. The block diagram of the apparatus is shown in Fig. 1. The specimen container E is inserted into a hollow cylinder A, the temperature of which is raised at a constant rate. The current in the heating element H_s is automatically regulated by a feedback control system in such a way as to remove temperature differences between the specimen and cylinder A. This current in H_s is registered on a recording milliammeter R_1. The specific heat of the specimen can be computed from the recorded chart of the heating current. The specific heat c_p is proportional to the square of the current and inversely proportional to the rate of temperature rise in the specimen. Hence,

$$c_p = \frac{R\,I^2\,\Delta t}{4{\cdot}18\;m\;\Delta T}$$

where R is the mean electrical resistance and I is the current intensity of the heater H_s during a time interval Δt; ΔT is the rise in temperature during interval Δt; m is the mass of the sample.

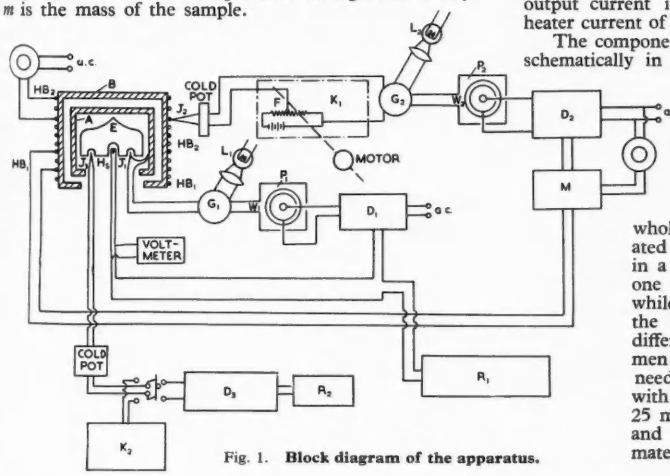

Fig. 1. **Block diagram of the apparatus.**

The feedback control system functions as follows :— A differential thermojunction $\mathcal{J}_1$ between the specimen and the inner wall of cylinder A is connected to a galvanometer G_1. If the temperature of the specimen is higher or lower than that of A, the galvanometer mirror is deflected. A light beam L_1 of constant intensity is reflected by the galvanometer mirror and projected onto the window W_1 of a phototube P_1, which is connected to an amplifier D_1. Thus, the intensity of the thermal e.m.f. of the differential thermojunction is converted into an electric current. The output current of D_1 is fed back to the heater H_s inserted into the specimen in E. Consequently, the current in H_s increases or decreases, according to whether the temperature of the specimen is slightly lower or higher than that of cylinder A.

Heating of cylinder A at a constant rate is provided by another feedback control system. A cylinder B, surrounding cylinder A, is heated at a constant rate by heating coils HB_1 and HB_2. The temperature of A is raised by thermal radiation from B. The reference signal, an e.m.f. increasing linearly with time, is produced by means of the rheostat F of a potentiometer K_1, which is connected in series with a galvanometer G_2 and a thermojunction $\mathcal{J}_2$, the latter being attached to the wall of cylinder B. Thus, the mirror of galvanometer G_2, which reflects light from source L_2 into window W_2 of phototube P_2, is deflected by the error signal, the difference between the e.m.f. of junction $\mathcal{J}_2$ and that of the e.m.f. terminals of potentiometer K_1. The current in heater HB_1 for cylinder B is then similarly controlled, as described above, and hence the temperature of B is raised at a constant rate. As the required input power of heater HB_1 is too great to be supplied directly from the output of amplifier D_2, a magnetic amplifier M is used to feed heater HB_1.

The temperature of the specimen is measured periodically by means of a potentiometer K_2, and for this purpose another thermojunction $\mathcal{J}_3$ is inserted into the specimen in E. For the same purpose, the e.m.f. of junction $\mathcal{J}_3$ is converted into an a.c. voltage and is amplified by a feedback-stabilised amplifier D_3, whose output current is registered simultaneously with the heater current of the specimen on the recorder R_2.

The components of the calorimeter used are shown schematically in Fig. 2. The specimen supports D, specimen heater H_s, cylinder A, cylinder B, and ordinary and differential thermojunctions $\mathcal{J}_1$, $\mathcal{J}_2$, and $\mathcal{J}_3$ are surrounded by a brass cylinder C, which in turn is surrounded by a thermal insulator. This cylinder serves as a shield against thermal-radiation loss. The whole system is enclosed in an evacuated bell-jar F. The specimen is packed in a glass capsule E with three apertures, one of which contains the heater H_s, while the others serve as containers for the ordinary thermojunction $\mathcal{J}_3$ and the differential thermojunction $\mathcal{J}_1$. The specimen supports D are constructed of steel needles, 1 mm in diameter at the base, with sharp points. The capsule E is 25 mm in diameter by 30 mm in height, and contains about 3 cm³ of sample material.

The heater H_s is made of constantan wire, 0·14 mm in diameter, formed into a double spiral with diameters of 1·2 and 8 mm respectively, and its resistance is approximately 60 ohms. The heater is supported by lead wires mounted to the bottom plate of cylinder A through silica tubes of 2 mm in diameter. The thermojunction J_3 for the measurement of the temperature of the specimen is constructed of copper and constantan wires, 0·06 mm and 0·14 mm in diameter, respectively. The differential thermojunction J_1 is made of wires similar to those used in thermojunction J_3, the intermediate part being made of constantan. The copper leads of this junction are connected to enamelled copper wires of 0·2 mm diameter in the bell-jar, for the purpose of decreasing the circuit resistance. Cylinder A is made of copper and is 40 mm in diameter, 70 mm in height, and has walls of 3 mm thickness.

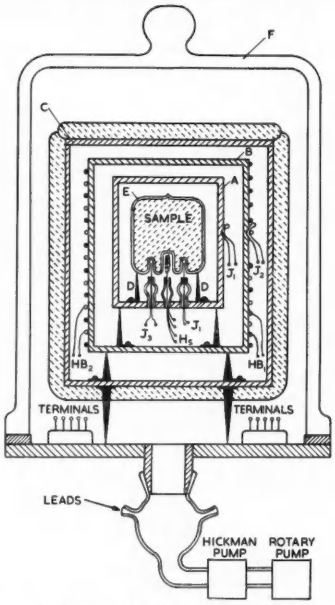

Fig. 2. **Schematic view of the calorimeter.**

Because of the nature of the feedback control system used for temperature control, a gradual fluctuation in the voltage of the a.c. source does not produce serious effects on the recorded chart. However, when unusual voltage fluctuations occur suddenly, a damped oscillation is observed on the chart; however, this oscillation dies out very quickly and its period is decided by the time-constant of heat conduction from the heater to the differential thermojunction J_1 through the specimen itself. Consequently, no special voltage stabiliser is used when fluctuations in the voltage of the a.c. mains are comparatively slow and small. The recording milliammeter R_1 (see Fig. 1) for heater H_s has a 10-mA full range with suitable shunt resistance, and is fitted with an oil damper, in order to record the mean current only, without the small fluctuations in the plate current caused by the automatic balancing.

For the purpose of confirming the satisfactory operation of the apparatus, the specific heat of a binary alloy of Mg_3Cd, in a temperature range of order-disorder transformation, was measured. The corresponding specific heat/temperature curve obtained from the recorded chart is shown in Fig. 3. This result agrees quite well with that from Nagasaki's measurement[3] by another method.

As mentioned above, a damped oscillation in the heater current was observed when input voltage fluctuated suddenly. This was noticed, for example, during measurements on the α-transformation of FeS, when the chart showed damped oscillations in the current, caused by an accidental variation of several volts in the a.c. line voltage. Similar oscillations were observed with continuous fluctuations in line voltage. In this case, as the specimen was enclosed in an evacuated glass capsule E, as shown in Fig. 2, several minutes were required for thermal equilibrium, owing to slow heat conduction from the heater H_s to the differential thermojunction through the glass wall of the capsule and the specimen itself. As a result, the effect of voltage variation in the a.c. line could not be compensated instantly.

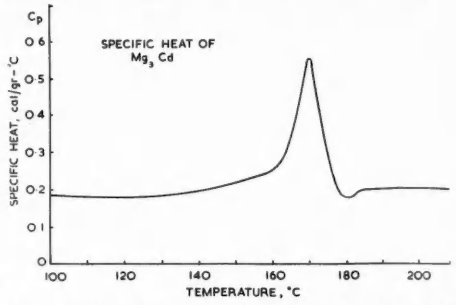

Fig. 3. **Specific heat/temperature curve of Mg_3Cd, obtained from the recorded chart.**

When control of the temperature of the sample or of the degree of evacuation in the calorimeter was not sufficiently exact, the necessary correction for heat absorption or emission by the specimen, due to thermal radiation or conduction, is not negligibly small. The maximum temperature deviation of the specimen from that of cylinder A in the course of measurements was some thousandths of a degree at a range corresponding to the flat portion of the curve in Fig. 3, and less than 0·01° C for the steep portion of the curve. In the case of measurements on a semi-conductor (FeS), the amount of the anomalous absorption of heat was about 300 cal/mol, and the maximum temperature deviation was of the order of 0·01° C at the range which corresponds to the maximum specific heat. In some cases of large anomalous specific heat, the curve of the heater current became oscillatory, when the heating rate was excessively rapid. This tendency was more accentuated when the curve of specific heat had a sharp maximum, as the maximum current of the heater H_s was limited to 90 mA by the output tube of the apparatus used. Consequently, accurate measurements with the present apparatus cannot be effected in the case of latent heat; however, in the case of small anomalous specific heat, this method can be employed with sufficient accuracy.

The following general precautions for adiabatic methods of specific-heat measurement by this method are suggested:—(1) Intimate contact between the specimen and the heater or junction must be maintained, in order to avoid thermal radiation between them. Under such conditions, thermal loss from radiation between the specimen and cylinder A can be minimised by increasing the sensitivity of the control system, without causing oscillations; the correction for radiation loss can, however, be computed from the recorded chart. (2) For the sake of avoiding fluctuations in specimen temperature, the heat capacity of cylinder B should be made as small as possible.

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Improvements in the Manufacture of Transformer Sheet

By H. H. MEYER and H. SCHLÜTER. (From *Stahl und Eisen*, Vol. 73, No. 26, December 1953, pp. 1706-1717, 13 illustrations.)

(*Concluded from May issue*)

PART II

It is known that, as a result of cold rolling, polarised grain orientation can be obtained, owing to slip and twin-crystal formation[26]. After a subsequent annealing, the polarisation may either be retained or, more frequently, so-called recrystallisation textures will be produced. In the case of iron, cold rolling, besides producing a less pronounced texture, results mainly in a cube face in the plane of rolling and a diagonal of the face in the rolling direction. These remain practically unaltered after an annealing below A_1. Above the A_1 point, a random distribution is obtained. Furthermore, it was indicated by Honda, Matsumoto and Kaja[27] that in iron the cube edge is the direction of easiest magnetisation. The magnetisation curve is much steeper and has a sharper bend along the cube edge, as can be seen from [100] in Fig. 3. This was confirmed for silicon-iron single crystals by Williams[28] in 1947. The next aim, therefore, was to find a rolling process which would make it possible, for instance, after recrystallisation, for the cube edge to be situated in the direction of rolling. Mention should also be made of the patents of Smith, Garnett, and Randall[29], and the work of Dahl and Pawleck[30], which enabled nickel-:ron alloys to be obtained with magnetic properties depending to a considerable extent on orientation.

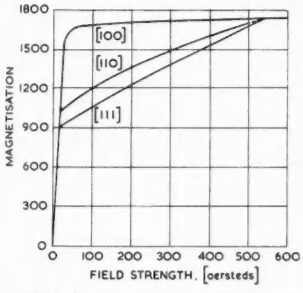

Fig. 3. **Dependence of magnetisation of iron on orientation.**

The first reports on cold-rolled sheet were published by Goss[31]. These were followed by a large number of similar investigations. In Germany, at the same time as Goss, the Krupp Company also carried out investigations; the results were communicated by Strauss, Stäblein and Meyer[22].

According to American literature, a steel with 2·9% to 3·5% Si was used. This steel is characterised by remarkably low carbon and manganese contents (0·02% and 0·06% respectively). In the subsequent treatment, a decarburising annealing apparently makes it possible to reduce the carbon content even further, to less than 0·01%. The steel is melted in either an open-hearth furnace or an electric furnace.

In the opinion of the authors, it is not absolutely necessary to maintain such a low carbon content in the ingot, since the carbon is removed in the decarburising annealing. In endeavouring to obtain a very low carbon content in the melt, there is always the danger that the oxygen content, and hence the amount of inclusions, may become excessive. However, it might be an advantage to melt and decarburise this type of steel in vacuum, in order to shorten the subsequent decarburising annealing process as much as possible. Some comparative tests made by the authors with open-hearth steels and electric steels failed to show any marked superiority in the electric steel.

Rybalko and Yakutovich[17] observed an improved texture with an increased silicon content up to 4·2%; however, cold rolling above 50 to 70% was carried out in only one instance, with annealing at 1000° C, followed by a cold rolling giving a critical strain of 4 to 6% elongation and, once more, recrystallisation.

In American literature, the following process has been described:—The ingots are hot-rolled into hot sheets of 2·5 to 2·7 mm, starting at a temperature of 1100° C and ending at 800° C. Sheet widths of 610 to 900 mm are mentioned. The hot sheet is annealed at 760° C, for from 24 to 36 hours, and allowed to cool down slowly. This is followed by pickling. The subsequent cold rolling serves to obtain polarised grain orientation. For instance, according to Goss[31], an initial rolling from 2·7 to 0·7 mm is carried out in four to six passes, with intermediate annealing at 870° to 980° C. This is followed by the finishing process, consisting of six to ten passes down to 0·30-0·35 mm. It is important that the temperature of the sheet during cold rolling should not be increased by more than 100° C. In the experience of the authors, it is sufficient if the cold rolling is made in at least two passes, for a decrease in thickness somewhat greater than 50%, so as to reduce a hot sheet from, for instance, 1·75 to 0·8 mm in thickness. After an intermediate annealing at 800-1000° C, performed preferably in a protective atmosphere, the sheet is rolled to its final thickness of 0·35 mm. The authors confirm the view expressed by Goss that better results are obtained by annealing in a continuous furnace than by box annealing.

A final annealing is also required to obtain the most favourable texture. This annealing should take place at between 1100° and 1400° C and in a hydrogen atmosphere, as it is necessary to achieve extensive decarburisation. For instance, in the case of "Hypersil"[32], it is reported that the sheet is cut into plates, insulated with magnesium oxide, and annealed for 60 hours at 1200° C. In this manner, a carbon content of less than 0·01% is obtained. Annealing may also be carried out in stacks or in a continuous furnace; however, the finished sheet then requires another annealing at 800° C after uncoiling. To reduce the risk of explosion, the annealing process is frequently carried out in a nitrogen-hydrogen atmosphere.

According to investigations by Sixtus[33], Ruder[34], and Waterfall[35], 60 to 70% of the crystals in the silicon-iron alloy have a rhombo-dodecahedral surface in the plane of rolling, and up to 95% have a cube edge in the direction of rolling, while 30 to 40% have a cube face in the plane of rolling. To obtain polarisation to this extent, it is apparently necessary to melt in vacuum, and a beneficial effect is obtained by maintaining the nitrogen content at 0·001%. The latter observation was also made by Morrill[13], who further considers that large amounts of impurities are detrimental. However, the use of very pure initial material and melting in vacuum also fail to produce satisfactory results. The assumption is that certain inclusions have a beneficial effect in preventing the growth of seed crystals with an unfavourable orientation, so that the favourably oriented crystals are able to grow more rapidly.

In order to determine whether adequate polarisation of the crystals has been obtained, measurements can be carried out with a magnet[36], over which a disc of the material to be investigated is suspended from a wire. The disc tends to rotate, so as to bring its direction of polarisation in line with the direction of the magnetic field, but is resisted by the torsional resistance of the suspension. The angular movement can be recorded for various positions of the magnet. If the apparatus is calibrated by means of a single crystal, the maximum and minimum values of the sinusoidal test curves of

polarised materials can be used as an indication of the quality of the texture. Tarasow[37] found that the results thus obtained were in good agreement with X-ray analysis.

From Fig. 4, it can be seen that, as a result of the polarised orientation, the magnetisation curve is considerably steeper than for cold-rolled sheet. For the same field strength, a higher value of magnetic induction is obtained with this kind of sheet than with hot-rolled sheet. To obtain an induction of 16 kilogausses in a hot-rolled sheet, a field of 100 oersteds is necessary, according to German specification D.I.N. 46,400. The same value of induction can be reached with a field strength of only 4 oersteds with the improved sheet. This is particularly important for large-size transformer manufacture, as it permits reduction of the number of windings used or operation at higher values of induction. In the United States, sheet of this kind is already extensively employed for power transformers, including large-size equipment[38]. Gordy and Somerville[38] describe, for instance, a strip-wound core known as " Spiralcore " for transformers of up to 3333 kVA.

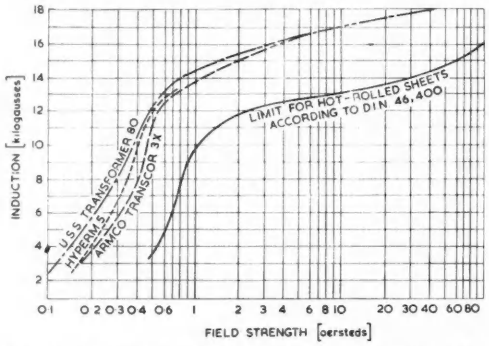

Fig. 4. **Curves of magnetic induction for cold-rolled silicon-steel sheet, with approximately 3·5% Si, compared with hot-rolled sheet.**

In the makers' literature, the permeability curves for " Transcor 3X " and " Transformer 80," which are the highest-grade transformer-steel materials of the Armco Steel Corporation and United States Steel, are well above the curve for transformer sheet. However, it is not stated whether they represent maximum values or guaranteed values. Also, they do not agree with the values calculated from the corresponding magnetisation curves. Measurements made by the authors on American material and on Krupp " Hyperm 5 " gave results situated between the two curves for the above materials. The guaranteed values for " Hyperm 5 " and " Hyperm 7 " have already been published elsewhere[39].

The iron losses are even more important. According to American data and measurements made by the authors, the improved sheet has L_{10} values between 0·6 and 0·8 W/kg and L_{15} values of 1·3 to 1·6, as against 0·95 and 2·3 W/kg, respectively, for hot-rolled sheet. In making this comparison, it should be noted, however, that no transverse specimens are taken from the sheet and the values for the hot-rolled sheet would be about 5% higher than those indicated above, if the transverse specimens are disregarded. The ratio of the L_{10} to the L_{15} losses is 2·3-2·4 : 1 for hot-rolled sheet, and slightly lower, i.e., 2·1-2·2 : 1 for cold-rolled sheet. Iron-loss measurements carried out by the authors, using a ferrometer and other instruments, gave results in good agreement with American data, showing that with the improved strip it is possible to reach L_{10} values of 0·6-0·7 W/kg, which cannot be obtained with hot-rolled sheet.

In Germany, strip-wound annular cores have been produced since 1933, mainly for relays, current-transformers, and magnetic amplifiers. Production for large-size transformers was too expensive under conditions prevailing at the time. More recently, however, less expensive types of material have been developed, and these are now being extensively employed for smaller sizes of ring-type transformers.

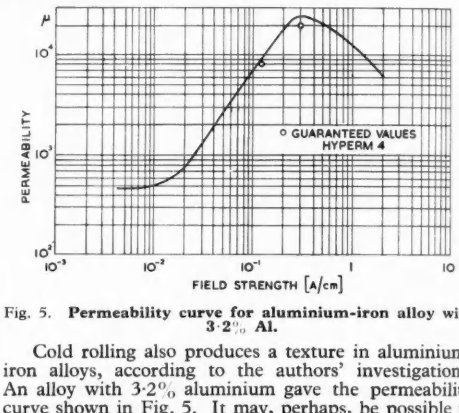

Fig. 5. **Permeability curve for aluminium-iron alloy with 3·2% Al.**

Cold rolling also produces a texture in aluminium-iron alloys, according to the authors' investigations. An alloy with 3·2% aluminium gave the permeability curve shown in Fig. 5. It may, perhaps, be possible to make further progress in the reduction of magnetic losses with materials of this type, as their specific resistance of 0·67 ohm-mm²/m is higher and the eddy-current loss will therefore be lower than that of silicon-iron alloy.

A further increase in maximum permeability, as well as a general improvement in the magnetic properties of transformer sheet, is obtained by cooling in a magnetic field. However, this method can be adequately applied only in the production of strip-type annular cores. For

(*Concluded on page* 258)

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Bonded Joints for Aircraft Control Rods

By D. CLERC and M. BOGAIEVSKY. (From *La Recherche Aéronautique*, No. 38, March-April 1954, pp. 57-62, 6 illustrations.)

The bonding of metal parts in aircraft with synthetic resins is by no means a new procedure, but its use has been confined exclusively to flat joints. This article describes the results of comparative experimental investigations on riveted and bonded joints in control rods and suggests that the fatigue resistance of bonded joints is on the average greater than that of riveted joints.

As the behaviour of aircraft controls directly affects safety, all their components are of vital importance. Experience shows that vibrations arising in an aircraft may set up, particularly in the control rods, parasitic stresses which become superimposed on the largely static and limited stresses they are designed to withstand, and it is therefore essential to obviate in all parts of such controls the risk of fatigue failure or damage.

With this end in view, fatigue tests on conventional control rods with riveted shanks and fork-ends were carried out. These tests showed that the riveting constituted the weak point, and a search was made for another jointing method, possessing greater resistance and capable of revealing any other weak points, for instance, in the fork-ends themselves.

The problem resolved itself into assembling two concentric tubular parts by a process giving the maximum of safety compatible with simplicity and economy. Preliminary investigation of known processes led to consideration of a modern bonding process.

Fatigue tests were carried out on specially designed testpieces, consisting of a metal tube and two end-pieces bonded with Araldite and possessing the same dimensions as the riveted rod assemblies previously tested. The fatigue tests were supplemented by static rupture tests.

Fatigue Tests on Riveted Rods

The fatigue tests were carried out on 15 samples from the same batch, divided into two groups, one of five and one of ten. As shown in Fig. 1, these were control rods with a tubular steel rivet joint between two duralumin components at either end.

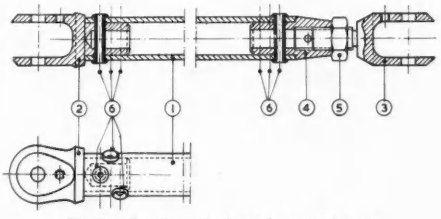

Fig. 1. **Section of riveted control rod.**
(1) Duralumin tube, 20 mm o.d., 16 mm i.d.; (2) fixed fork end; (3) adjustable fork end; (4) end-piece; (5) steel locknut; (6) tubular rivets (steel), 6 mm o.d., 3 mm i.d.

The testpieces were subjected to alternating stresses on Schenk and Dornier fatigue-testing machines at a frequency governed by the load and between 25 and 30 cps. Fig. 2 shows the various types of fracture observed. The results of the tests are shown in Fig. 3, and call for the following comments :—

(1) Of the fifteen samples tested, six showed type (*a*) fractures (Fig. 2), three type (*b*), three type (*e*), and the remainder one each of types (*c*), (*d*), and (*f*).

(2) Quantitatively, the results show marked scatter, more so in the first group (samples 1 to 5) than in the second group (samples 6 to 15), so that only the latter gives a Wöhler curve with normal dispersion.

Examination of the samples showed that riveting had been more carefully executed on the rods of the second group, the distance between the hole centres being more exact. The uniformity of the total results seems, therefore, to be connected with the quality of riveting.

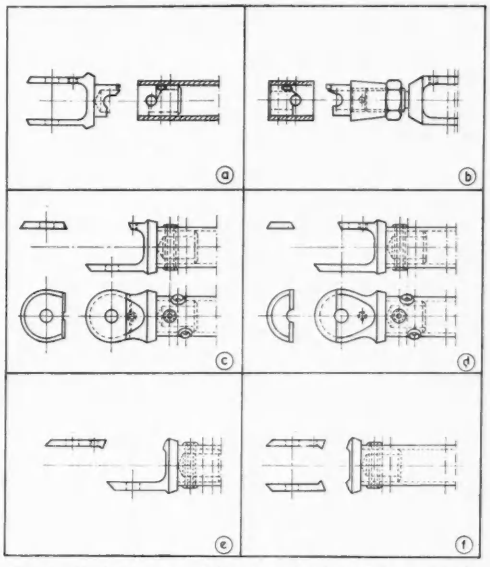

Fig. 2. **Various types of fractures in riveted control rods.**

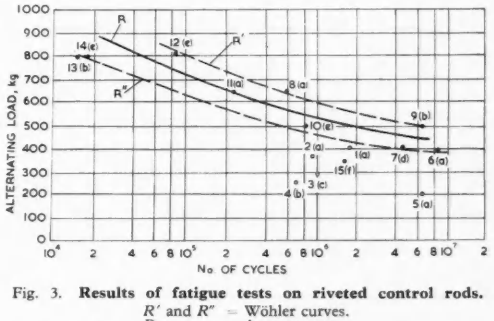

Fig. 3. **Results of fatigue tests on riveted control rods.**
R' and R'' = Wöhler curves.
R = Average curve.
The letter after each sample number indicates the type of fracture, as shown in Fig. 2.

General Observations on the Bonding of Metal Parts and their Application to Control Rods

The bonding of metal parts with synthetic resins, such as Araldite, Redux, Meltbond, etc., has stood the test of experience, particularly in aircraft construction, and has been used on the de Havilland Comet, the Bristol Britannia, the Boeing B.36, and other aircraft. In mass production it presents the advantages of economy and ease of qualitative supervision. However, use of this method has been confined chiefly to stringers or stiffeners for fuselage lining or wing panels, i.e., exclusively to flat joints. Its adaptation to the assembly of concentric tubular parts, such as control-rod shanks and fork-ends, presents a different problem, for, whereas flat metal sheet reacts to transverse deforma-

tions with only a slight flexural resistance, tubular parts respond to radial deformations with normal peripheral constraints tending to resist them effectively.

This fundamental difference involves the following implications :

(1) In the tubular joint secondary bending deformations are negligible and the adhesive undergoes practically none but shearing stresses.

(2) In assemblies of cylindrical tubular parts the thickness of the joint is positively determined by the choice of play between the parts.

(3) In these assemblies, there is no possibility of applying pressure during bonding.

The first two conditions are favourable for this type of assembly, but the third severely restricts the choice of adhesive. In this case, Araldite Type I was used.

Fatigue and Static Rupture Tests on Bonded Testpieces

Fig. 4 shows the two types of bonded testpieces used, (*a*) being the standard cylindrical type and (*b*) the tapered type, which possesses equal strength. The joint length (L) and the diametral play were 25 mm and 0·1 mm respectively for the tapered type and for the majority of the cylindrical type ; some tests, however, were also carried out on cylindrical testpieces with joint lengths of 10, 16, 32, and 50 mm and diametral play up to 0·4 mm.

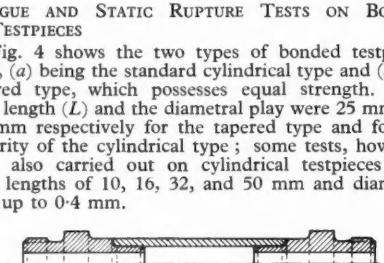

Fig. 4. **Sections of bonded testpieces used.**

These testpieces were fatigue-tested, in a similar way to the riveted rods, on Schenk and Dornier machines, while some were later subjected to static rupture tests on an Amsler machine. Altogether, 79 samples were tested and the results, some of which are shown in Fig. 5, revealed the influence of such variables as polymerisation period and temperature, type, length of joint, diametral play, nature and intensity of mechanical stresses, and test temperature.

The optimum polymerisation temperature seems to lie between 135° C and 140° C. Below this, at about 120° C, a notable drop in fatigue resistance was observed. The optimum shape of the components does not accord with the theory of elastic joints, and stress concentration at the joint ends appeared to be lower. The fatigue behaviour of the tapered pieces, though supposed to be of equal strength, was inferior to that of the standard cylindrical pieces. Furthermore, if the length of the joint is increased from 10 to 25 mm, the gain in resistance is over 100%, as against a theoretical 2%.

The length of 25 mm corresponds to a homogeneous assembly, where joint and shank resistances are substantially equal. Optimum play seems to be of the order of 0·2 to 0·3 mm, but for the sake of correct centering it is preferable not to exceed 0·15 mm.

It was found that complete separation of the bonded parts through fatigue alone could not be obtained. The reason is that in fatigue tests of this kind, the principal phenomenon (unless a metal part breaks) is a sudden increase in the amplitude of the motion, and this is always sufficient to stop the machine. In some samples, a few seconds before stoppage, a sudden increase in the temperature of the joint, amounting to about 50° C, was also observed.

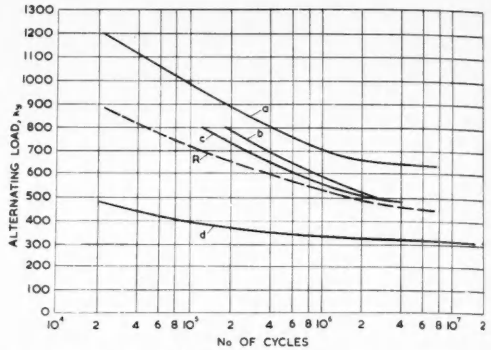

Fig. 5. **Results of fatigue tests on bonded control rods.**
(*a*) Wöhler curve for cylindrical testpieces with L = 25 mm and polymerisation temperature between 138 and 140° C.
(*b*) Wöhler curve for tapered testpieces with L = 25 mm and polymerisation temperature between 138 and 140° C.
(*c*) Wöhler curve for cylindrical testpieces with L = 25 mm and polymerisation temperature of 120° C.
(*d*) Wöhler curve for cylindrical testpieces with L = 10 mm and polymerisation temperature between 138 and 140° C.
R = Average curve for riveted control rods, as shown in Fig. 4, for purposes of comparison.

Complete separation occurred only after an additional static tensile test, and then only after slip, with a gradual decrease of the load, governed by the remaining length of the joint. In no instance was an abrupt separation observed, such as that occurring when a metal part is broken.

Finally, comparison of the static rupture load measured respectively on the apparently intact and on the damaged joint revealed considerable systematic static resistance loss after fatigue damage.

This experimentally defined damage therefore corresponds to an irreversible modification related to the structure of the bonded joint.

The residual resistance of the assembly after fatigue damage to the joint is probably due to a secondary phenomenon tending to resist slip. It would constitute adequate confirmation of this if the joint's dislocation surface were not everywhere cylindrical and parallel to the axis of the assembly. This favourable property appears to be specific to the form of assembly under consideration (cylindrical tubular parts).

The question is whether the destruction of the assembly is caused by an internal break-up of the adhesive or by the disruption of adhesion between the adhesive and the metal.

After detachment, it frequently happens that about 90% of the surface of one metal part—usually the end-piece is perfectly smooth, as if untouched by adhesive, while the rest is covered by a strongly adhesive film. The other metal part is covered by partially exfoliated adhesive layers.

It therefore seems that the disruption process is a mixed one, perhaps with disruption of the adhesive power predominating.

Conclusions

Comparison of the results of the tests on riveted control rods and bonded test pieces points to the following :—

(1) Under the experimental conditions described, the fatigue resistance of a bonded joint is on the average greater than that of a riveted joint.

(2) It is possible to make bonded assemblies whose fatigue and static rupture strengths are higher than that of the tube section itself, which seems impossible in a riveted joint.

(3) Under normal conditions, the fatigue strength

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Thermostat Metals and their Applications

By M. W. Riley. (From *Materials & Methods*, Vol. 39, No. 4, April 1954, pp. 102-105, 3 illustrations.)

Although most industries do not manufacture their own thermostatic controls, it is important for engineers to know the materials and principles involved in their construction, so as to facilitate their selection for specific applications.

The basic function of a thermostat is to convert heat into mechanical work. This is accomplished by its reaction to heat. A thermostat metal consists of two or more metals of differing coefficients of expansion, which have been bonded together into a composite sheet or strip. The metal with the higher coefficient tends to expand to a greater extent than the one with the lower, and the resulting deflection is utilised in various types of controls to perform three basic types of operation :—(1) Temperature indication, as in thermometers ; (2) temperature control, as in furnace controls ; and (3) compensation for temperature change, as in voltage regulators. To serve these functions, thermostat metals, made of a wide range of alloys, are produced to-day in many different shapes and sizes.

Selection of Alloys

In selecting a thermostatic device, the first consideration is the maximum temperature to which it will be exposed. The second is the temperature range of sensitivity within which the device is to operate. At the present time the maximum temperatures to which thermostat metals may safely be subjected are around 1000° F, though the most common elements operate in a range of approximately 50 to 300° F.

Since the deflection, and therefore the force exerted, is due to the difference in the coefficients of expansion of the component metals, this factor is one of the important considerations in selecting the alloys which make up the strip. The greater the difference in coefficients of expansion, the greater the deflection. In addition, it is necessary that the coefficients be reversible ; in other words, the alloy, after expanding with heat, must contract to the same extent on cooling. Only in this way can reliable duplication of results be obtained once the instrument is calibrated. Alloys used, therefore, are restricted mainly to solid-solution alloys, precluding those which exhibit changing solubility or phase changes with temperature changes.

Ever since 1897, when Invar, the 36% nickel-iron alloy was first produced, it has been used generally for the low-expansion side, since it has a coefficient of expansion of almost zero in a temperature range of 0 to 300° F. Above this temperature range its expansivity increases until it approaches that of iron. This range, however, is satisfactory for a great many applications.

For higher temperatures or for particular applications, modifications of Invar are used. By increasing the nickel content, the temperature range of low expansivity can be increased. For instance, an Invar-type alloy of 42% nickel, although there is some increase in expansivity, has a low coefficient of expansion up to 600° F. These Invar-type alloys can also be modified by the addition of chromium, molybdenum, or cobalt for high-temperature strength and resistance to scaling.

Other alloys used for the high-expansion laminate range from the plain carbon ferritic steels of medium deflection having coefficients of expansion of around 7×10^{-6} per ° F, through the chromium-nickel stainless austenitic group with expansivities of 8 to 10×10^{-6} per ° F, to special alloys such as the more recently developed high-manganese nickel-iron alloy with a 50% higher coefficient of expansion than existing nickel-chromium alloys. This alloy also has high electrical resistivity, making it particularly useful in electrical applications.

Thermal Bending

The thermal bending of a thermostat metal is affected by the difference in coefficients of expansion, the ratio of elastic moduli, and the thickness of the component metals. The radius of curvature of a strip is directly proportional to the difference in the coefficients of expansion of the component metals and the temperature change, and is inversely proportional to the thickness of the strip. It is immaterial which component has the larger modulus of elasticity, provided the ratio is the same. This ratio can vary from 0·3 to 3·3 and the element will still maintain 91% maximum curvature (thermal activity). Combinations with two great a difference in moduli, such as Invar-cadmium or Invar-hard rubber, have very little or no thermal activity.

The work a thermostat metal can do is proportional to the square of the difference in coefficients of expansion and proportional to the modulus of elasticity. To obtain the maximum work from a thermal element, the thicknesses of the components should be inversely proportional to the square roots of the moduli of elasticity. Consequently, the optimum combination is obtained when the moduli are equal. At this point the thickness of the components will also be equal, and no improvement in performance is possible by varying these factors. Also, the higher the modulus or stiffness, the more efficient the element will be.

Stress Problems

The hazards of excessive stresses are obvious. When the combination of thermal and mechanical stresses exceeds the elastic limit of the thermostat metal, a permanent set occurs. This set changes the calibration of the device and may render it unusable.

It is difficult to determine accurately the maximum permissible stresses for thermostat elements at various temperatures. Stresses in the element are due to thermal changes, mechanical loading, and fabricating operations, such as bonding, rolling, slitting, flattening, and heat-treating. The first two are relatively simple to determine, but the last is almost impossible, so that an adequate safety factor must be allowed.

For most thermostat metals having ferrous alloys for both components, the following maximum permissible working stresses f can be used :—

75° F, 50,000 psi ; 300° F, 49,000 psi ; 500° F, 43,000 psi ; 700° F, 6000 psi ; 900° F, 2000 psi ; 1000° F, 0-1000 psi.

Substituting the above values for f, the following equation can be used to determine the permissible working loads for cantilever elements and helix- and spiral-coil elements :—

$$P = \frac{fwt^2}{6L \text{ (or } R)}$$

where P = permissible load, lb ; f = permissible working stress, psi ; w = width, in. ; t = thickness, in. ; L = Length of cantilever, in. ; and R = radius arm of helix or spiral coil.

These permissible stresses are approximate only and should be used with caution.

Electrical Resistivity

An increasing number of modern electrical control devices, such as thermal relays, circuit breakers, and motor overload protectors, are actuated by thermostat-metal elements. The current passing through the strip generates heat, which in turn causes its deflection, thereby actuating the device. This type of operation requires elements with a wide range of electrical resistivity, as the amount of heat generated depends on this factor.

Elements manufactured to-day have an electrical resistivity ranging from 20 to 850 ohms per circular-mil-ft at 75° F. The highest range of resistivity was made possible by the development of the high-manganese alloy, which by itself has a resistance of 1050 ohms per circular-mil-ft. For those elements with resistivity over 500 ohms per circular-mil-ft, the nickel-chromium, nickel-chromium-aluminium-iron and nickel-manganese-aluminium-iron alloys are used.

For filling in required resistivities ranging from 470 to 20 ohms per circular-mil-ft, a third metal strip is added between the two components. This strip is made of a metal of varying resistivity and thickness, to provide the precise conductivity necessary. The resistivity of these " trimetal " elements can be calculated by considering the three strips as a parallel circuit. Another factor which should be kept in mind is that the resistivity of a metal varies with temperature changes, and that the resistance at the operating temperature and the rate of increase with temperature rise (coefficient of resistance) is equal in importance to that at room temperature.

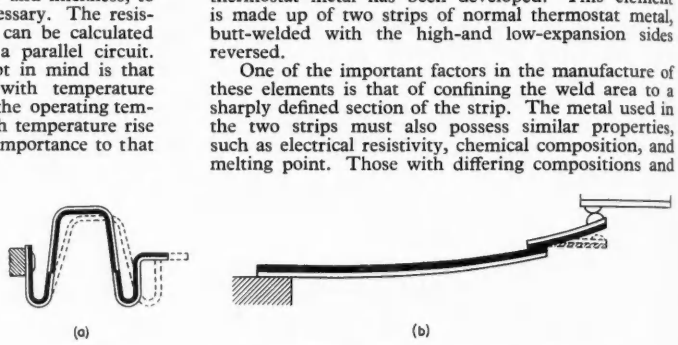


Fig. 1. **Applications of reverse-welded thermostat metals for producing (*a*) straight-line motion and (*b*) a more positive make-and-break action.**
The thick line represents the high-expension side of the element.

Other Properties

Other properties affecting the selection of the alloys for use in a thermostat metal are corrosion resistance, thermal absorption, thermal conductivity, and specific heat.

The amount of consideration given to the corrosion resistance of the element depends on the intended application of the unit. Since a great many of the thermostat metals are made of alloys in the stainless-steel class, they will normally resist the corrosion effects of domestic and industrial atmospheres. For applications which require immersion in steam or liquids, care should be taken in selecting alloys with increased chromium content to obtain the optimum protection.

In some cases, electroplating the element with nickel, zinc, cadmium, or other such metals, or dip-coating with lead or tin has been successful. However, any coating process will reduce the thermal activity of the element.

For those thermostat metals which employ ambient temperatures as the source of heat, the surface of the element should possess maximum absorption: i.e., a matte finish. The thinner the element, the finer the finish should be.

In cases where the heat is transferred to the element through the mounting fixture, the thermal conductivity of the metals used is an important factor. Thermal conductivities of most metals and alloys are roughly proportional to their electrical conductivities, so that a rough approximation of thermal conductivity can easily be made.

The specific heat of the metals used is important, but not much choice is available, as most thermostat metals have specific heats very close to 0·12 B.T.U. per lb per ° F.

Thermostat metals are stress-relieved and stabilised after the various manufacturing operations such as rolling, slitting, bonding, flattening, and fabricating of the finished part.

Bonding

There are three types of bonding processes which can be used in joining the laminates. An alloy with a lower melting point can be cast on one with a higher. This can be used only where there is a great difference in melting points. Another method is brazing. The difficulty here lies in the fact that the filler metal leaves a weak joint between the two components. The third type, and the one which is in most common use to-day, is welding in the solid state. In this last process, the metals are pressed together and reduced by a series of rolling and annealing operations until the desired gauge is obtained. With this reduction, a permanent intermetallic bond is assured.

Reversed Thermostat Metal

For some specialised applications, the reversed thermostat metal has been developed. This element is made up of two strips of normal thermostat metal, butt-welded with the high-and low-expansion sides reversed.

One of the important factors in the manufacture of these elements is that of confining the weld area to a sharply defined section of the strip. The metal used in the two strips must also possess similar properties, such as electrical resistivity, chemical composition, and melting point. Those with differing compositions and properties are difficult to weld satisfactorily. When the two strips to be reversed differ in thickness, lap welding is used. However, this kind of reversal is not as satisfactory as the butt-welded type.

The applications of reversed thermostat metal fall into three categories, i.e., compensation, straight-line motion, and positive make-and-break.

The thermostat in a flat-iron is an example of the reversed thermostat metal used to compensate for thermal overshoot and thermal lag, thereby ensuring accurate maintenance of the temperature desired in the iron. In some types of flame detectors or stack controls for domestic oil burners, straight-line motion of the thermostatic element is necessary for the efficient operation of the control. Since the common types of thermostat metal elements do not give linear motion if the temperature range is relatively wide, as in domestic oil burners, the reversed element is used, as shown in Fig. 1a.

A normal cantilever thermostat-metal element is essentially a creep device, slow in operation. With this gradual movement, in make-and-break devices, a slight vibration may well cause arcing across the contacts. The use of the reversed thermostat metal speeds the operation and ensures a more positive make-and-break action, as shown in Fig. 1b.

BONDED JOINTS FOR AIRCRAFT CONTROL RODS

(*Concluded from page* 244)

of the experimental bonded rods shows less scatter than that of the riveted rods.

(4) In case of damage through static or dynamic overloading, the riveted joints breaks abruptly, while the bonded joint gives way only gradually.

These observations naturally apply only to the concrete case investigated here, and cannot be applied without precautions to assemblies of other shapes and dimensions.

As bonding permits effective supervision of quality and is more economical than riveting, it would appear that this process could be used for the controls of conventional aircraft which are not called upon to fly in ambient temperatures above 70° C.

New Materials, Processes and Equipment

TRANSFER MACHINE FOR PRODUCTION OF AUTOMOBILE COMPONENTS

Built by Modern Tool Works Limited, of Toronto, a transfer machine, the first to be designed and manufactured in Canada, has been installed and is now operating in the Windsor, Ontario, plant of the Ford Motor Company. The machine enables Ford to mass-produce the upper and lower ball joints for the front-end suspension on their 1954 " Mercury " and " Monarch " cars. The production of small parts of this nature is a job particularly suited to this transfer machine. The operations performed are boring, facing, chamfering, rough and finish forming, drilling, spot-facing, reaming, and tapping.

Fig. 1

The fifteen work stations (Fig. 1) are designed around five basic sections or " islands," each consisting of a rigid casting which houses the indexing, locating, and clamping mechanisms. To the top of each section is fastened the hardened dovetail ways on which the fixtures slide. The five sections are spaced to conform to the requirements of the machine. The ways bridge the gaps between all sections and all assemblies are identical, carrying their own portion of the transfer bar. The cam bar for actuating the locating pins is treated in the same manner. With the sections then properly spaced and interlocked by the ways, the portions of transfer and cam bar are joined, forming the main structure of the machine.

Direct advantages of this type of construction lie in its accessibility and flexibility. Since each side of the " island " casting is completely machined, work stations may be located at any position on these faces. If a design change is made to the components, additional work stations are easily added, wherever an idle station has been provided. Similarly, complete section assemblies may be added or removed, as required. The operating units are standard " Modern " hydraulically operated self-contained units. Each unit is individually powered and by the use of pick-off gears has a wide range of speeds ; feed is infinitely variable.

When the operator has loaded the components, they are clamped by means of a power-operated wrench, which engages a nut at the base of the fixture (Fig. 2), During loading, the return conveyor, set in motion by the previous cycle, moves a fixture towards the loading station. When the conveyor comes to a halt, all work-holding units are automatically indexed from their

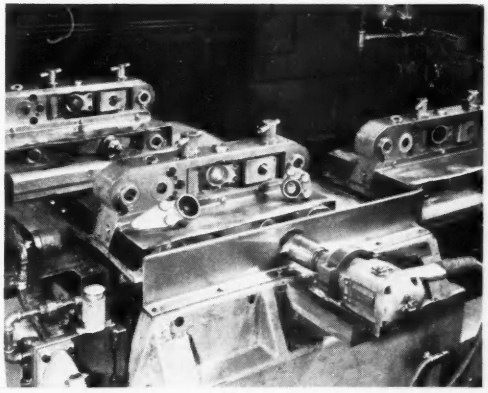


Fig. 2

respective stations to the next working station. At the completion of the transfer, the locating pins enter the fixtures and all fixtures are hydraulically clamped. The units then advance, perform their operation, and return. The transfer bar returns during the work cycle, ready to pick up the fixtures again for the next index. When the work holding units are indexed, a station is left idle, immediately adjacent to the loading station. The operator now moves the loaded fixture into this space by means of an assist cylinder. He then presses the cycle start button and the conveyor immediately delivers the next fixture onto the loading station and the cycle is complete. Fig. 3 shows the operating console and a rear view of the fixtures. At the right of the illustration can be seen the assist cylinder for moving loaded fixtures into position.

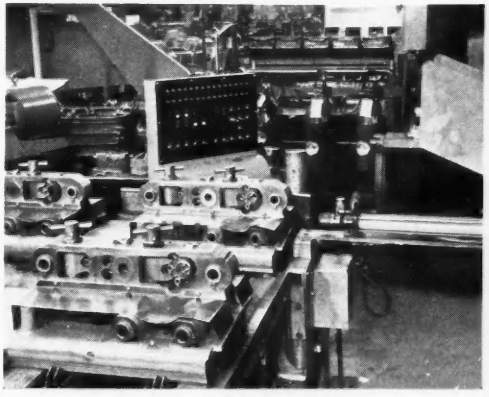


Fig. 3

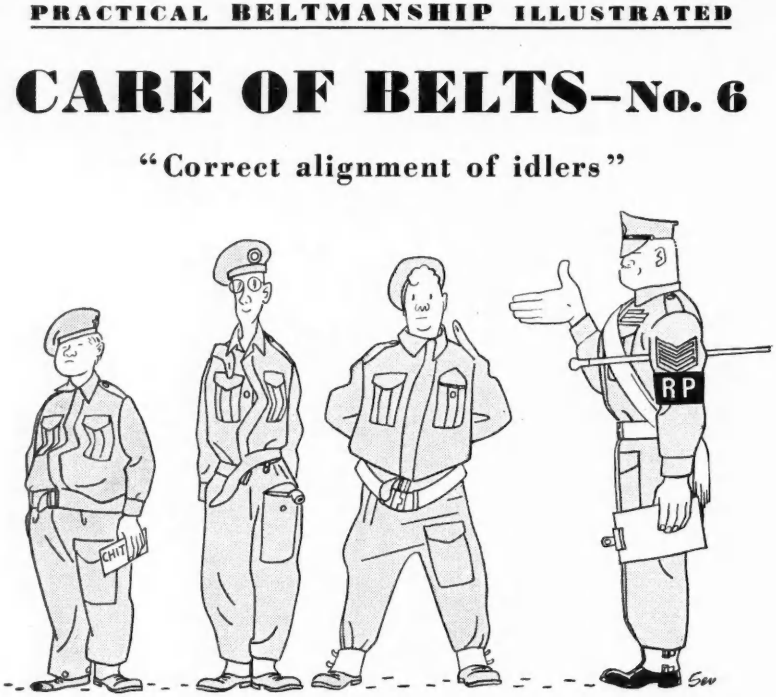
As each transfer is completed, a fixture is advanced into position on the return conveyor, to be carried back to the loading station. Each fixture in turn passes through a chip-removal station, where cuttings and coolant are automatically removed by blasts of compressed air. Chips at the work stations are channelled into a drag-type chip conveyor, which carries them to the far end of the machine, where they are deposited.

The indexing, locating, and clamping are all hy-

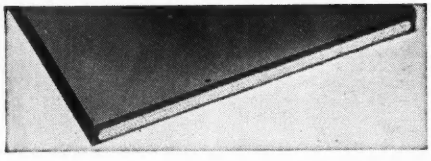
PRACTICAL BELTMANSHIP ILLUSTRATED

CARE OF BELTS—No. 6

"Correct alignment of idlers"



THE operator of a conveyor should look at his charge with the same critical eye as the owner of a new car. When installing a new belt, for example, check that idlers and terminal pulleys are correctly aligned. Correct installation followed by regular maintenance greatly increases the life of belting.
Goodyear Conveyor Belting is *completely* reliable. Since the early days of conveying, Goodyear have played a great part in helping forward developments and have proved the results of their extensive research in actual practice. A vast variety of installations all over the world are fitted with Goodyear Belts, many of which have been in operation for several years. Skilled Goodyear technicians make absolutely certain that every product upholds the Goodyear tradition of dependability.
You can find out everything about the care of industrial rubber products in the Goodyear Maintenance Manual—free on request. By choosing Goodyear industrial rubber products and by following the advice in this manual you will be sure of getting maximum life from your equipment. Write to Dept. K.6, Goodyear Tyre & Rubber Co. (G.B.) Ltd., Wolverhampton, for this valuable book.



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Specially made for conveying hot, highly abrasive materials when the combination of resistance to high temperature, extreme abrasion and severe flexing, is essential. It has all the qualities of a Grade "A" Belt, handling abrasive materials at temperatures up to 250°F. In 28 and 32 oz. duck, from three to nine plies, in widths, lengths and cover gauges to suit all conditions.

GOODYEAR

INDUSTRIAL RUBBER PRODUCTS

TRANSMISSION BELTING · V-BELTS · CONVEYOR BELTING · INDUSTRIAL HOSE

draulically operated and interlocked electrically. All units must perform their respective operations before an index can take place, and all fixtures must be properly located and clamped before any machining can be carried out. In the event that any one function of the cycle should fail, the operator can detect it immediately by a system of signal lights located on the console panel above the push buttons, as shown in Fig. 3. Should the machine be stopped part of the way through an automatic cycle, all work units which have started their cut will automatically back out of the work before coming to a complete stop. Those units which have not completed their work will advance again and finish the cut before another index can take place. The hydraulic power unit, together with the valves, is designed into a single compact cabinet. The valves are gasket-mounted and steel tubing and fittings are used throughout.

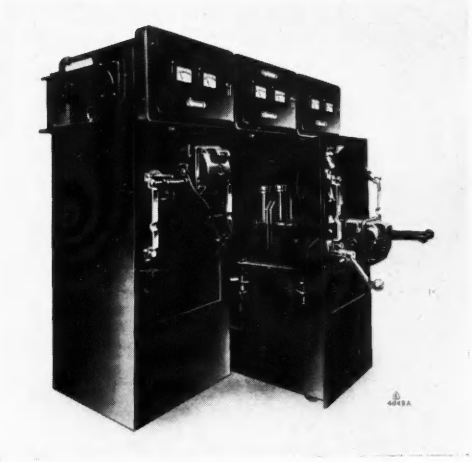
In designing the transfer machine, accessibility has been the keynote. As the tooling is completely exposed and ample space has been provided around each of the hydraulic units, the problem of changing cutters has been simplified and the time involved has been reduced to a minimum.

CIRCUIT-BREAKER UNIT

The latest addition to the range of electric switchgear manufactured by George Ellison Limited, of Perry Barr, Birmingham, is an oil circuit-breaker unit for 11kV, 3-phase systems, having a short-circuit rating of 250 MVA.

Arc-control devices of the cross-blast type are incorporated and are easily removed for contact inspection. Direct-acting over-current, shunt, and earth-leakage trips can be provided, as required. The circuit breaker can be manually closed or power-closed by spring or d.c. solenoid, as specified. The meter panel is designed to carry the usual indicating instruments, which are of the flush-mounting pattern. Any number of units can be mounted together to form a switchboard, and extensions can be readily made.

Each circuit-breaker unit comprises a stationary cell, surmounted by the busbar and current transformer chambers, and a withdrawable truck carrying the circuit breaker, as shown in the illustration. Self-sustaining gearing, operated by a handle, enables the breaker to be easily lowered to isolate the breaker. The circuit breaker can be locked against unauthorised closing and/or tripping. Interlocks prevent operation unless the breaker is in its working position or completely isolated. The truck can be locked against unauthorised isolation or returning to the busbars. It cannot be removed from the cell or replaced unless the breaker is fully lowered. The isolator sockets in the cell, through which connection is made to the circuit breaker, are screened on the lowering of the breaker by two automatic shutters, one on the busbar side and one on the outgoing side. Both can be independently locked.



When the breaker is opened, oil shock-absorbers arrest the moving contacts smoothly and without rebound. The main contacts are supported by " Tufnol " bushings and are easily replaced. Auxiliary contacts can be provided for the operation of remote indicating or signalling devices. The gases generated when the breaker operates are allowed to escape freely through a baffle chamber at the back of the breaker.

The current transformers are readily changed, should alterations in service conditions make this necessary. If required, a voltage transformer is mounted in an oil-filled chamber at the top of the unit.

FIRE DETECTOR FOR AIRCRAFT

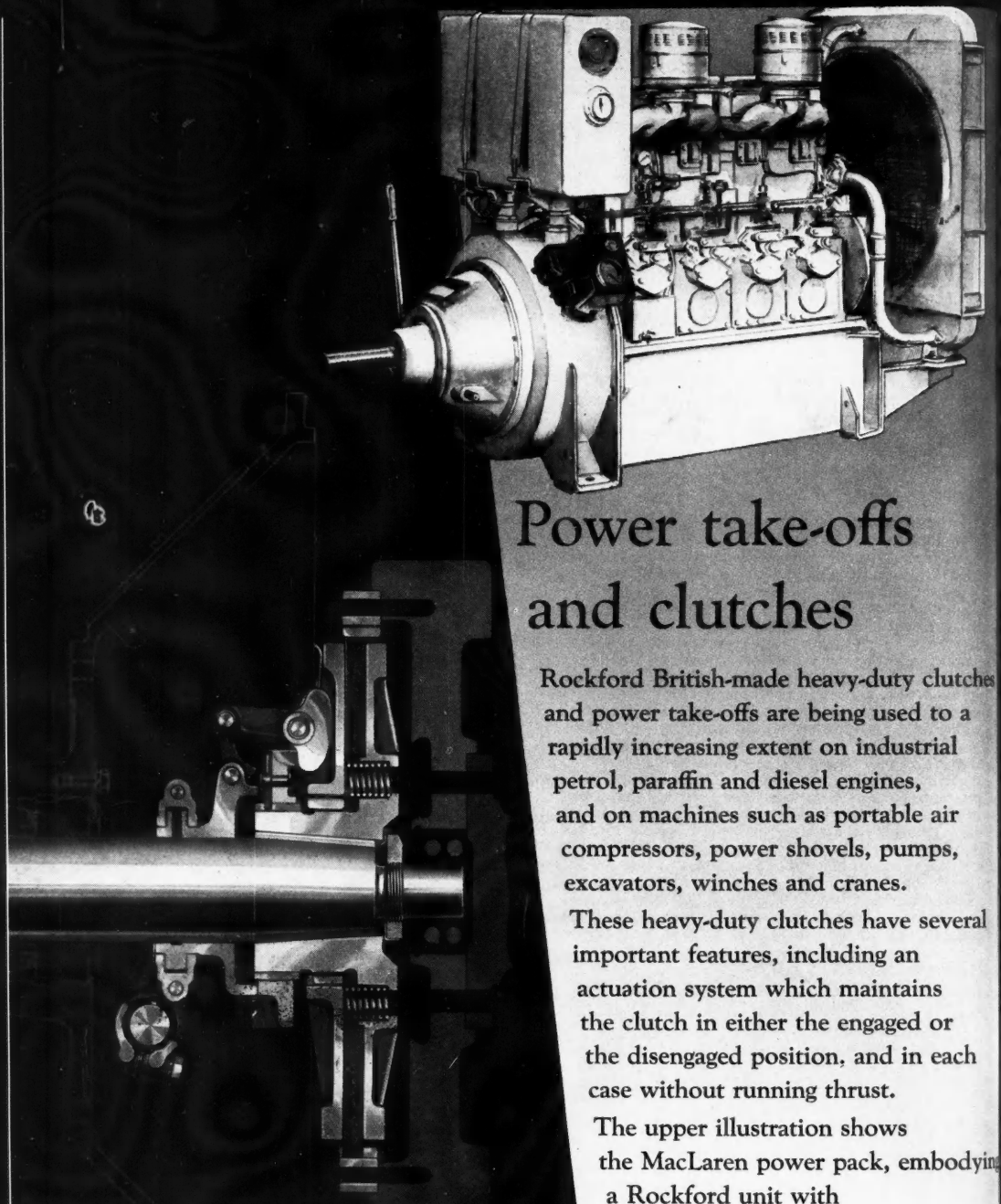
Among other stipulations laid down for aircraft power-plant fire detectors are the following :—They must be capable of withstanding without deterioration a statutory total of six minutes at 1100° C ; they must signal extinction of the fire in the shortest possible time, and must still be able to warn of any " re-strike," regardless of the extent and intensity of the earlier fire ; they must remain completely unaffected by contact with oil, water, fuel, dust, sea-water spray, hydraulic fluid, and de-icing fluid, and by subjection to accelerations of 12*g* in any direction, including a wide range of vibration conditions ; they must never give false fire warnings ; and they must not deteriorate as a result of prolonged disuse.

Unit fire detectors, of the well known type manufactured by Graviner Manufacturing Co. Ltd., of Colnbrook, Bucks., are capable of fulfilling the above conditions, but it is clear that unit detectors, located strategically in a power plant, may not detect a fire initiating between them, until it has become sufficiently widespread to embrace and/or transfer sufficient heat to at least one of them.

This objection has been overcome in the new Graviner " Firewire " detector, which is a continuous device, sensitive to temperature over its entire length. The sensing element of the detector is a stainless-steel capillary, containing a central wire electrode separated from the walls of the capillary by a temperature-sensitive material, which completely fills the capillary. The electrical resistance of this filling material decreases with an increase in temperature, and rises as the temperature falls. When the temperature of the element reaches a critical value, current flow in the circuit becomes sufficient to operate a relay in the fire-warning circuit. When the temperature of the elements drops to the resetting value, current flow in the circuit is insufficient to hold the relay. The detector operates on alternating current, and has been manufactured to suit both 26-V and 115-V ranges. Normal standby input current is low, being only 11mA on a 115-V supply.

The design of the " Firewire " is such that the temperature-sensing material helps the capillary to resist flattening and folding, should it receive a cutting or shearing blow. Thus, as each end of the wire is electrically connected to the warning system, its detecting capabilities are unimpaired even by fracture.

Other outstanding features of the new detector include light weight and a rapid response time of less than four seconds. Furthermore, it does not employ valve amplifiers, and is highly resistant to shocks and vibration. The simple movement of a test switch on a control box is all that is necessary to check the continuity of the sensing element and the serviceability of the entire circuit.



Power take-offs and clutches

Rockford British-made heavy-duty clutches and power take-offs are being used to a rapidly increasing extent on industrial petrol, paraffin and diesel engines, and on machines such as portable air compressors, power shovels, pumps, excavators, winches and cranes.

These heavy-duty clutches have several important features, including an actuation system which maintains the clutch in either the engaged or the disengaged position, and in each case without running thrust.

The upper illustration shows the MacLaren power pack, embodying a Rockford unit with single-plate clutch.

Descriptive booklet, with list of standard sizes, on application from :—
BORG & BECK COMPANY LIMITED,
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ROCKFORD

HYDRAULIC OVERLOADER

For a number of bulk-handling jobs, an overhead loader represents the logical development of the now widely used front-end type of loading shovel, and for this reason F. E. Weatherill Limited, of London, N.17, have now commenced full-scale production of the first hydraulic machine of this type to be manufactured in Great Britain or, as far as is known, in Europe.

Where maximum output is important, this fast-working machine should prove of great value, as it is capable of four loading cycles per minute. Depending upon the material handled, this can in turn mean a relatively easy 100 tons or more per hour. Furthermore, considerably reduced steering effort and infinitely fewer clutch and gear-change operations, with a consequent saving in operator fatigue and mechanical wear and tear, provide greatly simplified operation, combined with the ability to work successfully in spaces too small or too restricted for ordinary mobile shovels.

In the new overloader, the side arms are raised for the first part of their travel by a pair of main rams located on either side of the main frame towards the rear of the machine. At the extremity of their travel, a set of secondary rams take over and complete the overhead movement of the side arms and scoop. " Crowding " action of the scoop when pulling through the material is embodied, and is achieved by two additional hydraulic rams mounted on the side arms. One movement of a single control lever is all that is necessary to complete the whole loading and discharge operation. This movement also incorporates a braking effect, which automatically slows down the rate of movement of the side arms at the end of their travel just prior to the discharge of the load, and has the effect of assisting the satisfactory emptying of the scoop. The same control lever brings the scoop back to the loading position under hydraulic power.

A further point of interest from the point of view of safety is that the side arms do not travel past the operator and, although the load itself must obviously pass overhead, the cab is specially reinforced to provide protection from involuntary spillage. Discharge height and reach are ample for loading high-sided trucks or wagons.

The overloader is available with a ¾-or 1-cubic yard scoop, to which digger teeth may be fitted, if required. It is an integrally built machine, using the Fordson industrial tractor for power and transmission, the four-cylinder diesel engine providing 44 bhp at 1800 rpm.

HEAVY-DUTY FORK-LIFT TRUCK

The addition of a new diesel-powered fork-lift truck, Model 60DH, to their range of " Stacatruc " materials-handling equipment is announced by I.T.D. Limited, of London, W.11.

This model, which was exhibited for the first time at the Mechanical Handling Exhibition at Olympia, has a maximum capacity of 7000 lb and has been specially designed to meet the growing demand for a heavy-duty fork-lift truck whose overall dimensions fall within limits imposed by restricted space and other factors. Moreover, the new model incorporates certain outstanding features in design and construction, including oversize tyres, extremely smooth hydraulics, massive mast assembly, trouble-free 14-in. clutch, and compensated rear-steering axle. Perhaps the most important feature of all, however, is its " split-chassis " construction which ensures remarkably easy access, in under ten minutes, to all transmission parts for servicing purposes and which obviates the necessity of stripping a single component.

Models in the 60DH range are available with lift heights of 6, 9, 12, and 14 ft. Thus, 7000 lb of material can be handled in one load by one easily trained operator who can stack such loads up to 18 ft high or more, thereby freeing for production purposes valuable floor space normally used for storing. In addition, up to two three-ton trailers can be handled with ease, so that, with the load on the forks, these trailers together provide a total load-carrying capacity of more than 9 tons. The truck, which is powered by a Perkins P-4, 4-cylinder diesel engine, combines four-wheel stability with narrow width. This, together with a very responsive steering gear and a small turning circle, makes for extreme manoeuvrability in confined spaces and narrow gangways.

TOGGLE CLAMPS

A range of patent toggle clamps has recently been introduced by James Holt Engineers Ltd., of Bolton, Lancashire. These general-purpose clamps are of the quick-action type, effecting powerful action by simple pressure of the finger. An adjusting screw and lock-nut provide accurate setting of the clamping pad, while the range of clamping can be increased by means of single of double extension bars.

HOOVER F.H.P. MOTORS

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Sun Electrical Co. Ltd.

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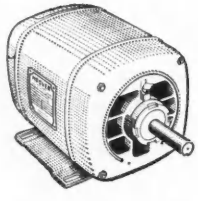

HOOVER LIMITED

INDUSTRIAL PRODUCTS DEPARTMENT

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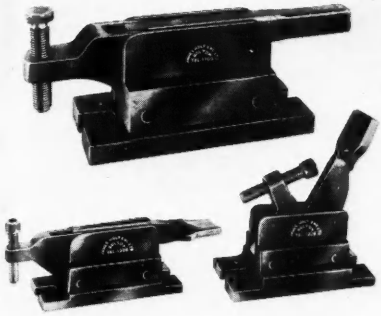
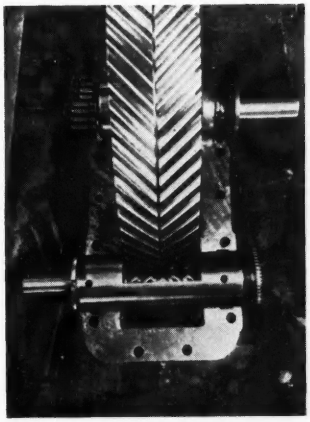


The flat design of these clamps makes them most favourable in milling operations, while they are particularly useful for jigs and fixtures, and especially for reducing machine loading time, where clamping is necessary.

"SIRA" SYSTEM OF GEARING

World-wide rights for the manufacture of "Sira" gears have been obtained by S. E. Opperman Limited, of Boreham Wood, Herts.

The "Sira" system of gearing, which was developed in Italy in 1946, employs helical gears, meshing progressively and smoothly, and can be divided into two classes, i.e., irreversible gears between parallel axes, and reversible gears with reduced diameters, respectively. In both classes, a plurality of teeth mesh at the same time, thereby reducing specific pressure to very low values, with consequent high efficiency and long life. Furthermore, although the axial pitches of the two gears are the same and the helix angles are different, the teeth mesh perfectly, owing to the fact that contact is not on the junction line of the centres, but in a zone displaced to the right or the left, according to the direction of movement.



In the irreversible gears, the shape of the tooth section, cut perpendicularly to the helices, is fully trapezoidal, and is very thick at the base, so as to give the teeth a resistance to bending and breaking strains far higher than that found in conventional gears. The mechanical efficiency is very high, about 72%, and is thus far superior to that of the conventional worm and pinion, which, when positively irreversible, never has an efficiency exceeding 40%. Moreover, in contradistinction to worm-and-pinion gears, with axes at right angles, the parallel axes of the "Sira" gear are often of great convenience, inasmuch as they permit more compact constructions, with better exploitation of available space. Finally, these gears do not place restrictions on reduction ratio and, in this connection, it is possible to produce irreversible "Sira" gears with reduction ratios of 1/2 or even 1/1.

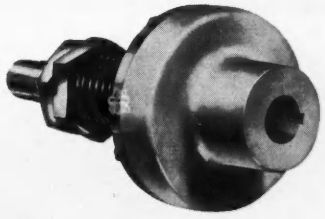
In the reversible class of gears, with a driving wheel of a given size and a given gear ratio, the diameter of the driven wheel is very much less than that required in a conventional module system. Thus, for example, in the case of a reducer with a 1/40 ratio, comprising only two wheels and transmitting 20 hp at 2000 rpm, the driven wheel of the "Sira" gear system has a pitch diameter of 725 mm, whereas, with the module system, the diameter would be about 3·2 m.

"Sira" gears provide a solution to many problems which cannot be dealt with successfully by ordinary gears, while their large contact surface ensures smooth and silent operation, with high efficiency, freedom from wear, and negligible temperature rise.

TORQUE LIMITERS

A complete range of torque limiters is being manufactured and marketed by Fords (Finsbury) Ltd., of Kempston, Bedford, and is believed to be the only range of its type being offered in Great Britain "off the shelf" to machinery designers.

Each torque limiter in the range is easily adjusted to transmit any desired torque within fairly wide limits, and automatically disengages as soon as the set torque is exceeded as the result of a mechanical overload in the drive. This ensures that no part of the machine is damaged through accidental overloads, and consequently no strengthening-up of parts is necessary to withstand overloads, nor are shear-pins required in any part of the machine. The torque limiter can be used as a coupling in a shaft, or combined with a V-pulley, a chain sprocket, or a gear drive. It can also be combined with an electric cut-out to stop the machine when an overload occurs and the torque limiter disengages the drive.



One of the most interesting features of the device is that when the cause of the overload is cleared and the machine is re-started, the limiter automatically resets itself in the same angular position, thus permitting the machine to resume operation at the exact cycle point of release. This is, of course, most important in some types of machinery, e.g., for packaging, where an exact cycle of operations must be maintained.

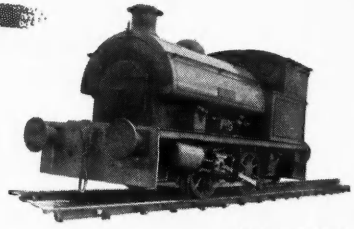
A standard range of sizes ensures complete interchangeability of the same capacity, while simple, robust construction ensures years of trouble-free operation.

The illustration shows one torque limiter in the range—the Number 10. This is adjustable, to transmit any desired torque between 100 lb-in. and 400 lb-in. The dimensions of the Number 10 are:—Overall length 10¼ in.; maximum diameter 4½ in.; weight 12½ lb. It is fitted with a 1-in. shaft at one end and a 1-in. socket at the other, both with standard keyways. Other types in the range cover torque transmissions below 100 lb-in. and above 400 lb-in.

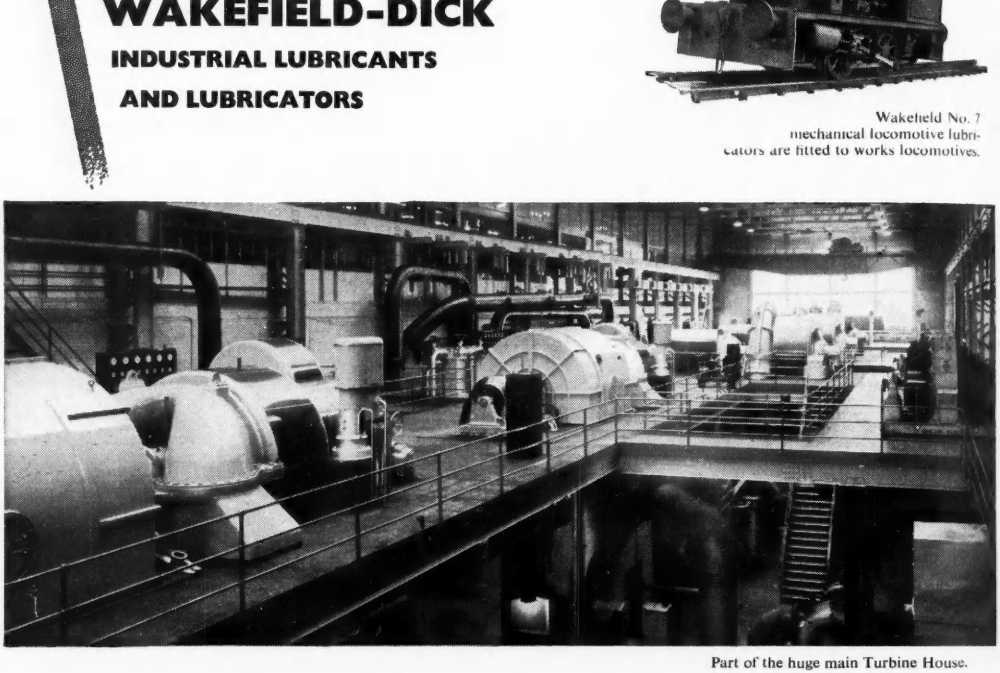
Consett Iron Co. Ltd. use

WAKEFIELD-DICK

INDUSTRIAL LUBRICANTS AND LUBRICATORS



Wakefield No. 7 mechanical locomotive lubricators are fitted to works locomotives.



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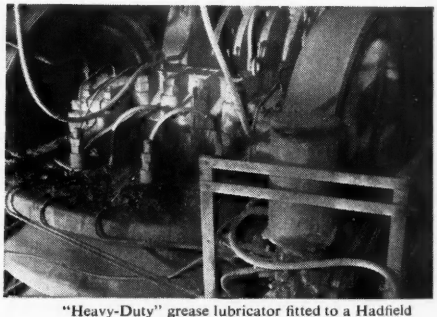


"Heavy-Duty" grease lubricator fitted to a Hadfield primary crusher.

INDUSTRIAL WAKEFIELD-DICK LUBRICANTS

WAKEFIELD-DICK

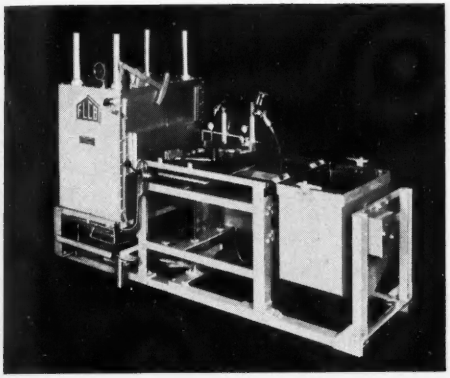
INDUSTRIAL LUBRICANTS AND LUBRICATORS

C. C. WAKEFIELD & CO. LTD., LONDON, W.1.

SEMI-AUTOMATIC SHELL-MOULDING MACHINE

A new development in the range of machines working on the shell-moulding process is the " Shelmolda Duplus," manufactured by Fairbairn Lawson Combe Barbour Ltd., of Leeds, which combines the productive capacity of the two-oven machine with the compactness of a single-oven machine.

The machine, which is semi-automatic, has a single gas oven, thermostatically controlled, and is fitted with a mechanism which enables it to deal with two pattern plates at once and to present ready to hand the shell which has just been cured. This mechanism is operated pneumatically and is controlled by a conveniently placed lever. An additional automatic mechanism reverses the dump-box and, after a pre-determined period, rights it once more. Pattern plates are 24 × 16 in., with an effective area of 23 × 15 in. The maximum depth of the pattern is 4 in., with 1¾ in. ejection of shell from the pattern plates. The dump-box has a capacity of 2 cwt.



The temperature of the oven is thermostatically controlled, and can be varied, as required. The machine can easily be connected to the main gas supply, and the blowing nozzle and spray gun, with air transformer on the machine, are suitable for connection to the compressed-air supply mains. The interval between reversing the dump-box and righting it again can be varied at will. Both operations—investing and curing—are therefore within the operator's control and require only a minimum of physical exertion.

The output of the machine is of the order of 50 to 60 moulds per hour, and the floor space occupied is only 8 ft 6 in. × 3 ft 3 in.

EXTRUSION PRESS FOR ALUMINIUM POWER-CABLE SHEATHS

Direct extrusion of aluminium sheaths has long been of interest to the cable maker, but past efforts made to develop the process have been unsuccessful. After a close study of the problems involved, and after preliminary experimental work, British Insulated Callender's Cables Limited, of London, W.C.1, concluded some years ago that, if the extrusion of aluminium sheaths is to take its place as a normal production process, the latter should permit the use of solid billets and commercial grades of aluminium, and low extrusion temperatures, preferably not exceeding 300° C. Furthermore, charging time should be reduced to a minimum, so as to prevent overheating of the cable while stationary in the press, and the process should have the ability to produce sheathed cables in long, continuous lengths, and satisfactory welds between successive billets. Finally, there should be avoidance of deformation and metallurgical features at " stop-marks," i.e., the point on the sheath which is within the die, when the cable is stationary for recharging.

No existing type of press combining all these features was available. Accordingly, B.I.C.C. and the Loewy Engineering Co. Ltd., of Bournemouth, co-operated in the development of an extrusion press which would provide the required facilities. The result of their combined efforts is the " Alsheath " press, made by the Loewy Engineering Co. Ltd., and installed at the Prescot Works of B.I.C.C.

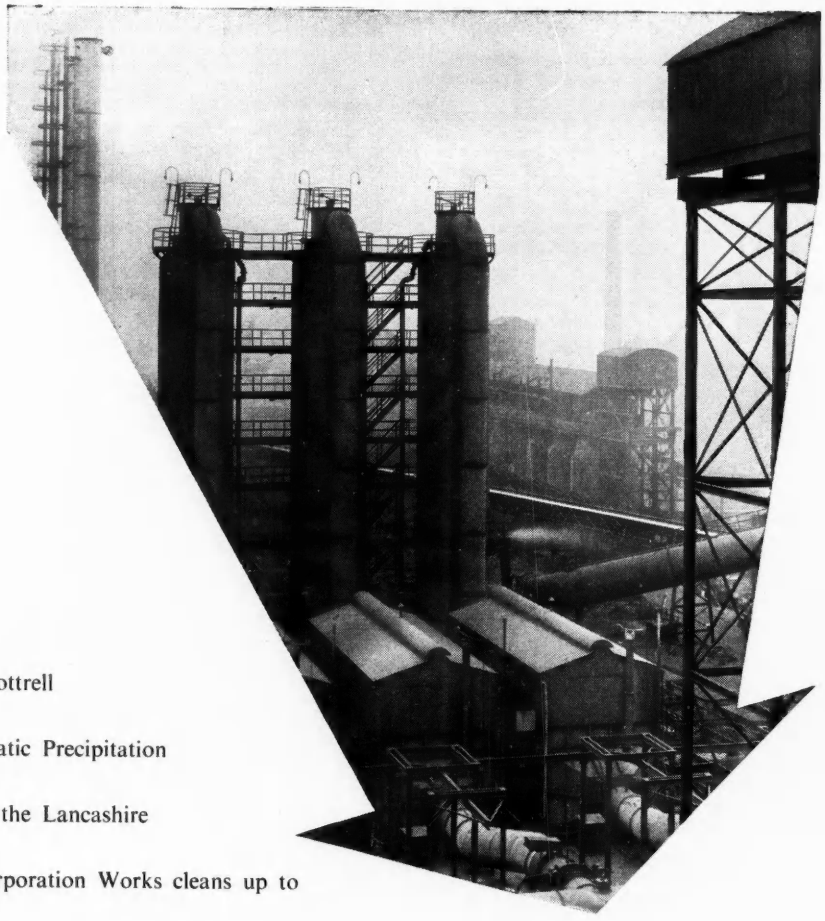
This press, which is the subject of patents and patent applications in Great Britain and other countries, is believed to be unique. It is hydraulically operated with two horizontally opposed cylinders, each 45 in. in diameter, operating at 4280 psi pressure, and each giving nominally 3000 tons capacity. Twin billets are extruded through a common core and die, to give sheaths ranging from 1·4 to 3·5 in. in diameter.

The cable passes through the press at right angles to the axis of the cylinders. This permits the use of solid billets and reduces to a minimum the length of cable exposed to the heat of the press. The extrusion tools are mounted in such a way that they retain their positions, and the gap between them remains constant, independent of elastic deformation caused by expansion or contraction under heat. The extruded sheathings are therefore free from weakness at stop-marks. Special controls ensure that the speed of extrusion from the two containers is constantly balanced. Mechanical loading facilities have brought down the recharging time to a matter of seconds. Special attention has been devoted to the prevention of air inclusions. All major movements are controlled by servo-operated valves from the central pulpit shown in the illustration, providing for fully automatic control or for individual control, as desired.

Trials to-date indicate that all the initial objectives are being met and the press is approaching the stage when it will take its place as a routine tool in cable manufacture. Enough cable has been sheathed to show that the stop-marks are satisfactory from the dimensional and metallurgical aspects ; they comply with the appropriate bend-test requirements and they can withstand high hoop stresses. The welds formed between successive billets (as distinct from stop-marks) are not discernible in the extruded sheath.

With aluminium of 99·8% purity and extrusion temperatures of 280° C, the extruded sheaths are in the lightly annealed condition. Tensile strength is 5·0 to 6·0 tsi, and elongation on a length of two inches in the longitudinal direction of the sheath is 30% to 50%, depending on diameter and thickness. The grain size is fine at all parts of the sheath including stop-marks. These properties ensure that the springiness associated with cold working is largely eliminated.

Much remains to be done in equipping the press with the tools required for a comprehensive range of



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cable size and in proving its performance over that range. Sufficient has been done, however, to indicate that a thoroughly practical solution of the problems which have engaged the attention of cable makers and of press designers for many years has been found.

TUBE-STRAIGHTENING MACHINE

A new tube-straightening machine has recently been built by the Bronx Engineering Co. Ltd., of Lye, Worcs., for the precision-straightening of steel tubes of between 1 and 4 in. o.d. The design comprises two driven work rolls and five opposed pressure rolls, the rolls being disposed vertically, so that the tube is always supported on the work rolls. This construction facilitates the insertion of tubes into the nip of the rolls, and the pass line is constant for all tube sizes.

Each driven work roll is independently operated from a 15-hp motor, the transmission consisting of V-rope drives from motors to gear box and thence to the rolls by universal mill-type couplings and spindles. Couplings can be disconnected in a few seconds, when the rolls require removal for re-dressing, etc.

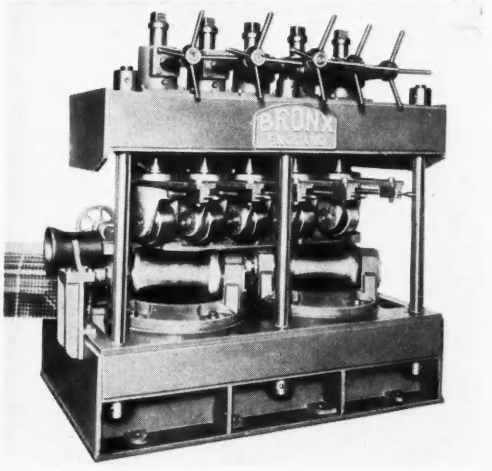


Fig. 1

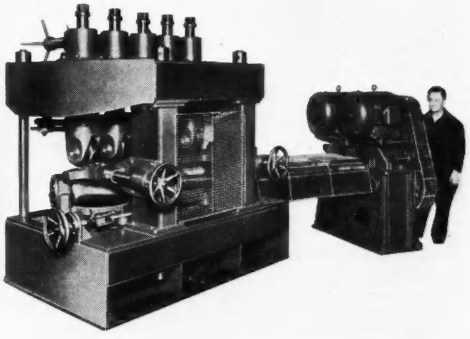


Fig. 2

For non-ferrous tubes of very light gauge, the machine can be supplied with a special type of drive, to avoid marking the highly finished surface. If required, special-purpose machines can readily be constructed, using standard roll units.

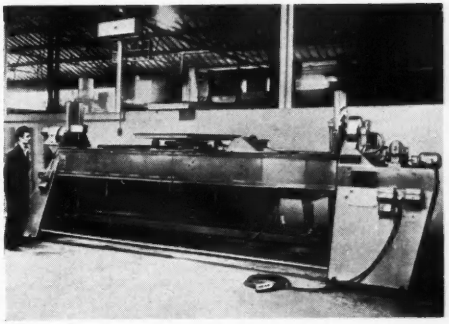
The front and rear views of the machine are illustrated in Figs. 1 and 2 respectively.

UNIVERSAL SELF-BALANCING WELDING POSITIONER

The largest welding positioner in the " Twinner " range manufactured by Donald Ross & Partners Ltd., of London, N.W.1, is their new 6-ton universal self-balancing machine.

The four-foot square worktable (which can be larger, if desired), as well as being carried in heavy-duty bearings, is also supported by four outboard bearings provided to absorb shock loading when loading the workpiece. The worktable is driven by a power unit through a worm-reduction gear box and final bevel drive, all built into the heavy steel fabricated crosshead. A dog-clutch is provided, so that the worktable can be manually rotated, if desired, and a heavy friction band is fitted, to prevent the table from revolving too freely. A revolving welding earth-return is fitted to the bottom of the worktable shaft.

The workpiece is normally balanced to within about an inch on the rotational axis of the worktable. The crosshead is then raised by a geared motor unit driving two lead screws housed in the vertical arms of the main U-beam. These lead screws engage floating nuts in the crosshead, which is raised until the centre of gravity of itself, worktable, and workpiece is in line with the trunnions on the end pedestals. In this position all moving parts of the positioner are in balance and the small power units provided can rotate and tilt the workpiece through 360 deg. on both axes, if desired. A slipping clutch is fitted on the tilting movement, so that, if the workpiece has not been properly balanced, the power unit will not be overloaded. Operation of the positioner is by means of a four-station, pushbutton remote control.



The gap between pedestals is 15 ft and can be increased or reduced to meet requirements. Maximum working load with a high factor of safety is 6 tons, with a centre of gravity 18-in. from the face of the worktable. Also available are 1-ton and 3-ton sizes of the same design.

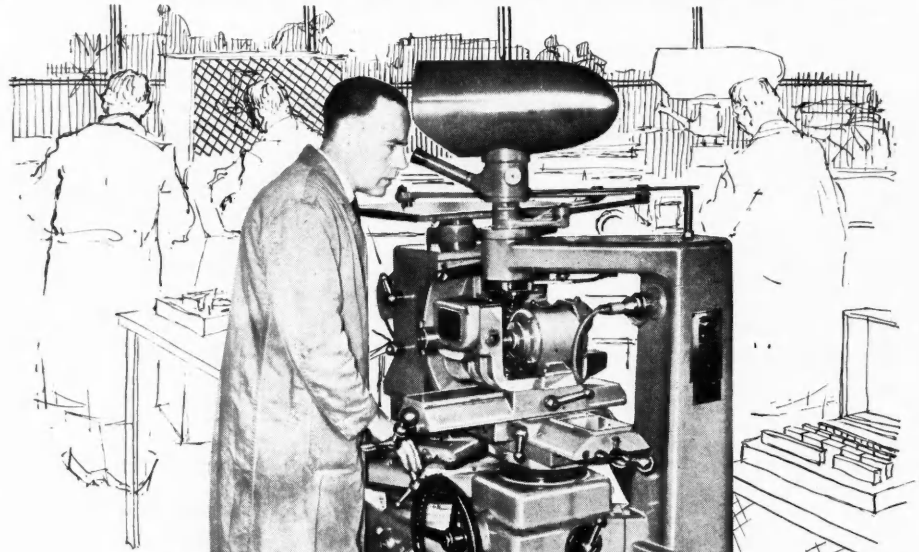
HIGH-SPEED, AUTOMATIC GEAR-HOBBING MACHINE

A new high-speed, fully automatic gear-hobbing machine, known as the " Hydrax," has been designed and built by David Brown Machine Tools Ltd., of Manchester.

Special, patented design features enable this machine to produce gears of various types and sizes at a production rate equivalent to that of several hobbing machines of conventional design.

The principle of the new machine, which weighs 9½ tons and occupies a floor space of only 7 ft × 6 ft 6 in., is that the work axis is inclined to the direction of hob feed at the helix angle of the gear to be cut, while the hob slide is set angularly to the worm angle of the hob. When cutting, the hob is traversed in a vertical direction along the helix and very considerable reductions in hob traverse are made, compared with conven-

THE WICKMAN OPTICAL PROFILE GRINDING MACHINE



makes the operator his own inspector

Combining the functions of a universal toolroom grinding machine, a fifty-to-one pantograph, and a microscope, this machine will not only produce the most intricate profiles and die-forms in a single operation, but enables the operator to check the accuracy of the form produced as the work proceeds.

Accuracy is not affected by wheel wear and specially shaped wheels are not required. Attachments are available for circular form grinding and indexing.

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tional methods. By plunge-feeding the hob to depth, the absolute minimum of hob traverse is required.

The cutting cycle is fully automatic and is controlled by a single pushbutton. Work loading and unloading are effectively performed by a quick-acting clamping arrangement fitted in the work spindle, the two operations being under the control of a single lever. Hydraulic feeds are infinitely variable, and rates of up to approximately $\frac{1}{8}$ in. per revolution of the work are easily obtained, producing gears well within the limits of accuracy required for subsequent shaving operations. Lead cams or differentials are not required for spiralling, and the use of simple hob and table drives, with a minimum of gears, obviates the multiplication of small errors.

VARIABLE-TILT SHAPING MACHINE

Designed and built by the Orton Machine Company, of San Francisco, Cal., a new tool, known as the "Variable-Tilt Shaper," is claimed to tackle successfully one of the most tedious and time-consuming jobs in the aircraft industry, i.e., the machining, to varying angles, of the edges of cast aluminium-alloy form blocks used as bottom dies in the fabrication of bulkheads, frames, ribs, and many other structural parts of aircraft.

Since the parts formed must fit into aircraft with tapered fuselages, wings, and other components, the angle of the edges of these form blocks, which are usually two inches in thickness, changes constantly, but not uniformly, along their entire contour. Hitherto, no machine has been available for cutting these edges, and the form blocks have had to be made by hand. This involves a laborious process of filing and of constantly checking results with a protractor, accuracy depending entirely on the skill of the workman. Thus, for example, a typical form block, such as that used for making the door ribs of a large aircraft, required no less than three days to file the edges. With the new machine, however, the same job can be turned out in only three hours by two operators, one of whom feeds the form block into the rotating cutter, while the other manipulates a large control wheel, which varies the angle of the cutter as the work progresses.

The machine comprises a vertical cutter suspended above the surface of a steel table by means of a circular mounting. A cutter-head unit and a 5-hp electric motor are mounted on an outer quadrant, which slides over an inner quadrant on bronze ways. The inner quadrant is mounted on the frame of the machine. By turning a control wheel, which actuates a worm gear and pinion, as shown in the illustration, the outer quadrant can be rotated over the inner quadrant. No lock is required to maintain its position, owing to its substantial design. The cutter-head unit is so located that the top edge of the cutter is at the exact centre of rotation of the outer quadrant. Consequently, as the angle of the cutter is changed, the top edge remains stationary and the cutter rotates around the point where the top edge contacts the form block. In this way the machining angle can be varied accurately from an exact line which is the top contour of the form block.

As the work is machined, one operator continuously adjusts the angle of the cutter by bringing the pointer on a protractor scale into conformity with the readings indicated on the template. A guide, mounted on the non-tilting inner quadrant, is located immediately above the cutter. The other operator feeds the form block into the cutter by bringing the template against the guide, which is in full view. An adjustment on the inner quadrant is provided to raise or lower the point of rotation of the cutter, so that blocks up to 6 in. in thickness can be machined. Practically any shape of block can be processed, provided it is of uniform thickness. It is claimed that accuracies obtained are exceptionally high, because the circular mounting of the machine magnifies the operator's control. A slight change in the angle of the cutter, which would not be perceptible to the eye, is easily observed on the protractor scale, which is a segment of a very much larger circle.

Machines of this type are being supplied to the Ryan Aeronautical Company, of San Diego, Cal., and it is estimated that they will cut seven-eighths of the time previously required to machine form blocks.

CIRCULATING PUMP FOR CENTRAL-HEATING SYSTEMS

The many practical advantages afforded by forced circulation are such that it is rapidly replacing the thermo-syphon system in practically all industrial and domestic hot-water heating systems. However, the efficiency and reliability of any central-heating installation operated by forced circulation depend primarily on the accelerator, and only a unit designed and constructed specifically for this duty can satisfactorily fulfil the operating requirements of modern heating practice.

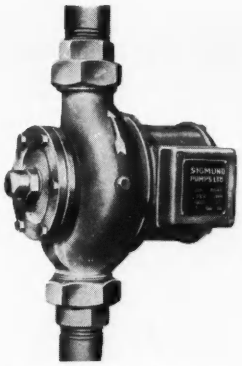
Such a unit is the Sigmund "Thermopak," manufactured under licence from a Swiss firm by Sigmund Pumps Limited, of Team Valley, Gateshead. This is a compact, light-weight, super-silent, streamlined electric accelerator of precision construction. The complete unit comprises a single- or three-phase electric motor and a pump designed to obtain a high output and, at

Unique

"Newallastic" bolts and studs have qualities which are absolutely unique. They have been tested by every known device, and have been proved to be stronger and more resistant to fatigue than bolts or studs made by the usual method.

C. P. Newall & Co., Ltd.

POSSILPARK GLASGOW · N



the same time, to offer little resistance to the passage of the water when the accelerator is stopped.

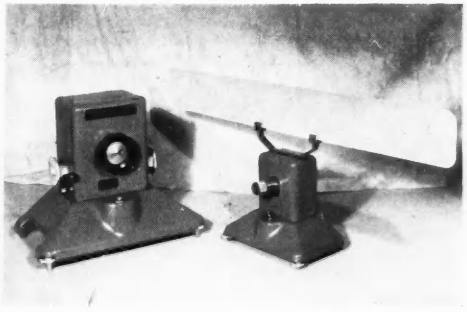
The entire rotating element, including the electric motor, is separated completely from the stator and windings by a shell of non-magnetic metal. The bearings, very widely dimensioned, and made of stainless steel and bronze, are lubricated by circulation of the water and do not require any other lubrication, so that the " Thermopak " accelerator needs no attention of any kind. The bearings are not located in the main circuit, but are lubricated by water drawn off from the circuit along the shaft of the unit, resulting in outstanding reliability and trouble-free performance. The absence of a stuffing-box has many favourable advantages. There is no gland leakage, no need for constant tightening of glands, no mechanical seal, and absolute water-tightness is assured.

Other advantages include simplified installation, quicker and more uniform heating of premises, and the possibility of heating with a lower water temperature during mild periods. Furthermore, boiler output can be employed to the fall, and in severe climatic conditions there is less danger of freezing, if the " Thermopak " is kept running when the heat is turned off.

WAVEGUIDE X-BAND WATTMETER

The double-vane, torque-operated waveguide X-band watt-meter manufactured by The Wayne Kerr Laboratories Ltd., of New Malden, Surrey, is an improved form of the single-vane, torque-operated wattmeter described by Cullen and Stephenson, and is intended for the absolute measurement of power between 1 and 75 watts, with an accuracy of 1% from 75 to 10 watts, falling to 10% at 1 watt.

Two thin metal vanes are mounted, one-quarter guide-wavelength apart, on a spindle suspended inside a short vertical length of rectangular waveguide by means of a quartz fibre. E-plane corners connect the vertical waveguide with horizontal input and output guides, fitted with standard waveguide connectors. Power flowing through this waveguide gives rise to a torque on the vanes, owing to the attractive action of the electric field. This torque can be related to the power flow by measurements involving length, mass, and time only, so that an absolute measurement of power is made, independent of any secondary electrical standards.



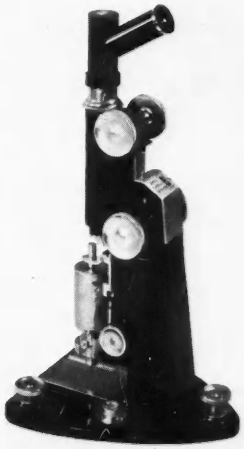
The especial advantage of the double-vane instrument is that the indicated power is much less dependent on the standing-wave ratio of the load than it is in the case of the single-vane instrument. A standing-wave ratio of 0·9 leads to an error in power of only 0·5%, and for greater mismatch a correction is easily applied. The power absorbed or reflected by the instrument is negligible.

MICRO-HARDNESS TESTER FOR RUBBER

Sponsored by the International Standards Organization, the I.S.O.-type micro-hardness tester for rubber, manufactured by Nash and Thompson Limited, of Tolworth, Surrey, was developed at the request of the Dunlop Rubber Company, and is intended for testing both large and very small specimens of rubber.

The instrument gives results compatible with those obtained with the larger British Standard instrument, in that the indentation of a small loaded ball, measured in 0·01-mm units, gives the B.S. hardness number. This number is converted to International Hardness Degrees by reference to the chart in B.S. 903.

The instrument will accommodate specimens from 4 mm to 45 mm in diameter, and from 1 mm to 35 mm in thickness. It is possible, under certain conditions, to take readings on samples as small as 2 mm in diameter, and down to 0·5 mm in thickness. For the hardness testing of large sheets, the mounting slide used for normal measurements is withdrawn, the instrument is placed on the sheet, and readings are taken through the base.



Basic features of the instrument are a measuring head containing a ball-ended pin and an indenting weight. When the pin is loaded, it sinks into the rubber specimen a distance dependent upon the hardness, and the movement of the upper end of the pin is observed and measured through a microscope. The specimen is located by an annular clamping tube which is free to slide in bearings. The pin itself moves in frictionless bearings located within the clamping tube.

The instrument, which is 16 in. in height and stands on a base 8 in. square, weighs 15¾ lb, and can be supplied in a polished wooden carrying case.

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CLASSIFIED ABSTRACTS

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ELECTRIC SWITCHGEAR

Disconnecting Unloaded Transformers and Unloaded Lines by means of Minimum Oil-Content Circuit-Breakers.

By H. ROHRER. (From *Bulletin Oerlikon, Switzerland*, Vol. 33, No. 299, 1953, pp. 52-58, 12 illustrations.)

THE phenomena occurring in switching out unloaded transformers and unloaded lines have frequently been discussed within recent years, and the essential features of these switching operations have been dealt with in numerous publications. However, only relatively few measurements are at present available on the magnitude of overvoltages occurring in practical operation.

In this article, a short survey is given of the results of switching tests on unloaded transformers and unloaded lines, carried out not only with minimum oil-content circuit-breakers of normal design, but also with resistor circuit-breakers. The conclusions to be drawn from these tests and from many years of practical experience with minimum oil-content circuit-breakers are as follows :—

(*a*) Overvoltages occurring on switching out unloaded transformers with tank oil and minimum oil-content circuit-breakers are not dangerous in practice.

(*b*) The higher voltages observed in exceptional cases when switching out unloaded transformers are not caused by the circuit-breakers only, but are also due to the properties of the transformers. Conditions leading to these overvoltages are not as yet fully explained.

(*c*) When, in special cases, higher overvoltages occur on switching out unloaded transformers, these can be limited by the installation of surge arresters, or can be greatly reduced by the use of circuit-breakers with the resistor-step.

(*d*) Backfires are likely to occur when switching out unloaded lines with tank oil and minimum oil-content circuit-breakers without forced streaming of the means of quenching. The number of backfires is, however, of no importance in service; the important factor is the magnitude of the overvoltages. Moreover, with the length of line used in modern practice, both the number of backfires and the magnitude of overvoltages can be reduced by the use of circuit-breakers with resistor-step.

FATIGUE OF METALS

Experiments on the Alternating-Stress Fatigue of a Mild Steel and an Aluminium Alloy at Elevated Temperatures.

By P. G. FORREST and H. J. TAPSELL. (From an advance paper submitted to *The Institution of Mechanical Engineers, London*, May 1954, 12 pages, 13 illustrations.)

AT air temperature, many materials show a definite fatigue limit which is unaffected by a speed of testing between 200 and 10,000 cycles per minute. Jenkin (1925-1926) and Jenkin and Lehmann (1929) have shown that, for higher speeds (up to 500,000 cpm), the fatigue limit increases, and their results seem to indicate that, at very high speeds, a certain time is required to cause fracture at a given stress range, independent of the speed. However, their tests were limited to a duration of 10,000,000 cycles, so that additional evidence of fatigue behaviour at these speeds would be necessary to confirm their conclusions.

At high temperatures, materials do not show such definite fatigue limits, the stress/endurance curves having a continuous downward trend in stress up to maximum duration (in laboratory practice, about 10^8 cycles). Fatigue strengths are therefore quoted, not as fatigue limits, but as stress ranges which can be withstood for a certain number of stress cycles without fracture, and it is found that, under these conditions, the fatigue strength does not depend on the speed of testing.

In view of the importance of fatigue behaviour in engineering structures, where both cyclic stresses and high temperatures occur, as, for example, in steam, oil, and gas engines and in turbines, it was decided to carry out research to determine how the effect of cyclic speed on fatigue strength depended on temperature. This paper, therefore, describes a series of alternating-stress fatigue tests at several speeds between 10 and 8000 cpm on a normalised 0·17% carbon steel at air temperature, 400, 450, and 500° C, and on the aluminium alloy R.R.58, in a fully softened condition, at 200° C. It is shown that, for the mild steel, the fatigue strength at air temperature depends mainly on the number of cycles of stress, irrespective of the cyclic speed, but that at 400 to 500° C, failure at a given stress range occurs after a certain time, which is approximately independent of the speed. For the aluminium alloy at 200° C, there is evidence of a small speed effect, but fatigue failure chiefly depends on the number of stress cycles applied, and not on the time of application.

In addition, a study has been made of the dynamic stress/strain relations, and these are shown to be useful as a guide to variations in fatigue strength with temperature and speed. Furthermore, they provide a means of determination of the stress redistribution, when plastic strain occurs in bending fatigue, and it is shown how this, together with the effect of testpiece size, may account for the difference between bending and direct-stress fatigue strengths.

The Fatigue Strength under Bending, Torsional, and Combined Stresses of Steel Testpieces with Stress Concentrations.

By R. C. A. THURSTON and J. E. FIELD. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, April 1954, 9 pages, 3 illustrations.)

THE work described in this paper forms part of a general research into the resistance of metals and alloys to complex systems of combined fatigue stresses, and was carried out on behalf of the Advisory Council of the Department of Scientific and Industrial Research and of the Air Ministry. It is a continuation of Gough and Pollard's work on the fatigue behaviour of metals under combined flexural and torsional stresses, alternating (both in phase), the mean stress of the cycle being zero.

In previous investigations by Gough, Pollard, and Clenshaw, under the same general research programme, determinations were made of the intrinsic and vee-notched fatigue strengths of the first seven steels here investigated, under various combinations of bending and torsion. The intrinsic fatigue limits were found to fit reasonably to an ellipse quadrant, and the notched fatigue limits to a two-constant displaced ellipse or " ellipse arc."

The bulk of the present paper concerns the behaviour under combinations of bending and torsional stresses of testpieces with transverse holes, for the same seven

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steels. The fatigue limits under the various stress combinations have been found to fit reasonably to an ellipse arc of the same form as for the vee-notched specimens. The similarity in form of the ellipse arcs for the seven materials supports the theoretical conclusion that the shape of the curve is dependent only on the shape of the hole, and is independent of the nature of the material. The information given on strength reduction factors under various combinations of bending and torsion, together with tables of the results of supplementary static tests, should be of use in such problems as crankshaft design.

The paper also includes the results of flexural and torsional fatigue tests on an aircraft crankshaft steel, with other forms of stress concentration. These results are compared with those on two steels of similar composition.

FOUNDRY PRACTICE

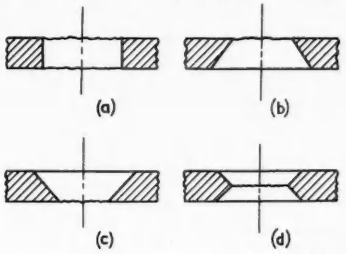
Inserts at the Bottom of Risers of Steel Castings.

By V. BATĚK. (From *Slévárenství, Czechoslovakia*, Vol. 2, No. 1, 1954, pp. 14-17, 15 illustrations.)

FOR the purpose of reducing the cross-section of the joint between riser and casting, so as to facilitate removal of the riser by impact, an insert, consisting of a disc with an opening large enough to permit flow of liquid metal, can be employed.

Inserts made of sand can be applied only where the surface of the casting is flat. However, inserts made of stronger materials can be placed between the mould and the riser during tamping, without risking breakage. Consequently, such inserts can be applied irrespective of the shape of the top of the mould.

The shape of the hole in the insert must be so designed that the plane of fracture during removal of the riser is well defined. In the case of shape (*a*), it is uncertain where the riser will break off; if the break occurs at the top, as in shape (*b*), the remnant will be



too large; if the break occurs at the bottom, as in shape (*c*), the casting may become chipped. The best shape is that shown in (*d*).

The savings obtained by the use of inserts are particularly important in the case of castings made of special materials, for which riser removal is a very laborious process, and also in cases where specially shaped inserts can be used; after removal of the risers, all that is necessary is to grind the parting points, machining being unnecessary.

It is reported that inserts are now being used on a large scale in the steel foundries of the V. I. Lenin (ex-Skoda) Works, at Pilsen, Czechoslovakia, and that substantial savings have been obtained by their use.

INTERNAL COMBUSTION ENGINES

Air Flow in a Naturally Aspirated Two-Stroke Engine.

By F. J. WALLACE and M. H. NASSIF. (From an advance copy of a paper submitted to *The Institute of Mechanical Engineers, London*, May 1954, 23 pages, 25 illustrations.)

IN this paper, the problem of the scavenging of naturally aspirated, two-stroke cycle engines by utilisation of wave effects in the exhaust and induction system is treated theoretically and investigated experimentally by systematic variation of the exhaust and induction system, as well as engine speed.

In the theoretical treatment, accuracy is achieved with a minimum of numerical computation by the adoption of the theory of waves of finite amplitude and the use of charts, wherever possible. These two features constitute the most significant departure from List's thorough analysis (1949-50), which is based throughout on the small wave theory and in which little attention appears to have been paid to the simplification of numerical work. The theoretical section is divided into two parts dealing with (1) the analysis of cyclical pressure fluctuations in the engine cylinder and pipe system, and (2) the treatment of the gas-exchange process in the cylinder on the basis of "perfect mixing" and the derivation of conditions for dynamic similarity.

A novel experimental technique is used, air from an external compressor being admitted to the cylinder of the motored engine through a rotary valve. In this manner, release pressures, comparable with those obtaining in the firing engine, are attained, while the effects of high temperatures, which are of secondary importance in relation to wave phenomena, are eliminated.

The experimental work is divided into two parts, i.e., tests corroborating the wave theory, and systematic air-consumption trials with variable induction-pipe lengths and exhaust systems, incorporating (a) plain pipes, (b) an exhaust ejector similar to that described in the Kadenacy patent specifications, (c) an expansion chamber, and (d) a diffuser.

The general conclusions are that: (1) Good agreement between observations and analytical results is obtained; (2) high air consumption is possible with natural aspiration, provided that effective use is made of wave action by correctly designed exhaust and inlet systems; and (3) satisfactory scavenging is achieved only if, in addition to the external pipe system, the engine speed and geometry also conform to certain requirements conveniently expressed in the form of dimensionless groups.

IRON AND STEEL

The Effect of Deformation, Temperature, and Chemical Composition on the Formation of Martensite in Austenitic Stainless Steels.

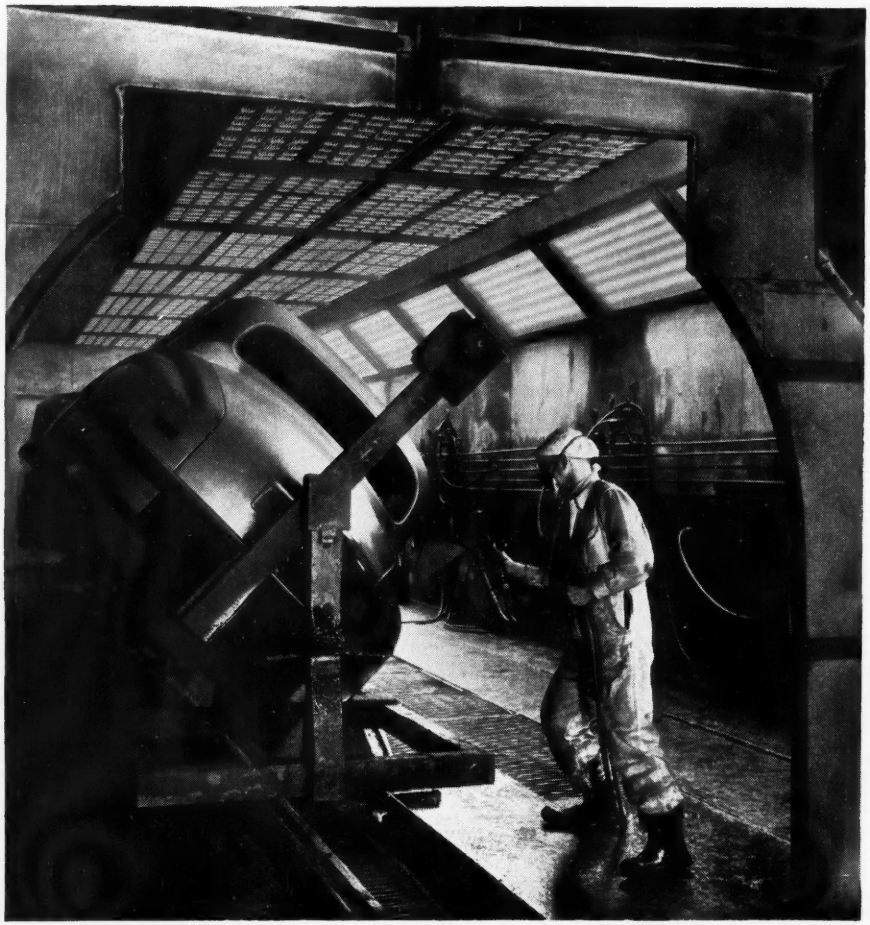
By T. ANGEL. (From *Jernkontorets Annaler, Sweden*, Vol. 138, No. 3, 1954, pp. 117-141, 18 illustrations.)

THE formation of martensite as a function of plastic strain, stress, and deformation energy has been determined in a tensile test for a number of austenitic stainless steels. The results are in accordance with the reaction-path theory of martensitic transformation given by Cohen.

The deformation of martensite is regarded as a mode of deformation competing with the slip mode of deformation. The governing factor in the formation of martensite induced by deformation is the supply of mechanical energy through deformation. Stress is here of primary importance, as deformation is merely a consequence of the formation of martensite through the action of stress. Strain, whether it be the consequence of the martensitic or the slip mode of deformation, is, however, assumed to be of some importance in affecting the stress conditions, so that local peaks of stress may be formed, activating some martensite embryos.

The influence of temperature is discussed in terms of the relation between the martensitic and the slip mode of deformation. At very low temperatures, it was found that the martensitic mode is the dominating, if not the only, mode of deformation. At higher temperatures, slip becomes the prevalent process of deformation.

Within a narrow temperature range, a radical change in the stability of the austenite was observed, and referred to the transition between the two modes of



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deformation. In this range, a characteristic temperature was chosen, to give a measure of the stability of the austenite. The effect of composition on the austenite stability was measured by means of multiple regression analysis, applied to a number of heats of varying composition. Contrary to the views often expressed in the literature, it was found that chromium, silicon, and molybdenum act as stabilisers of the austenite in the martensitic transformation, in the same way as do nickel, manganese, carbon, and nitrogen. The results largely confirmed the investigation by Eichelman and Hull on the austenite stability, where another measure of stability was employed.

Finally, the extraordinary increase in stress observed in the stress/strain curve was treated quantitatively, and was found to be proportional to the amount of martensite formed in the tension test and also to the carbon content of the martensite.

MAGNETISM

An Automatically Recording Magnetic Balance.

By T. HIRONE, S. MAEDA, and N. TSUYA. (From *The Science Reports of the Research Institutes, Tôhoku University, Japan*, Series A, Vol. 6, No. 1, February 1954, pp. 67-76, 8 illustrations.)

A NEWLY designed magnetic balance for plotting automatically the magnetisation temperature curves of magnetic materials is described in this article.

In the new instrument, the sample is suspended from one end of the beam of an analytical balance, and from the other end a small magnetic needle is suspended through the centre of a small solenoid. The force acting on the sample is compensated by the mutual force between the needle and the magnetic field produced by the feedback current through the solenoid. This feedback current is produced by a phase-sensitive capacity analyser connected to a pick-up condenser, one plate of which is attached to the lower end of the balance pointer. By recording this current automatically, changes in magnetic susceptibility caused by temperature variations can be traced. As a result, the lengthy and tedious work normally associated with magnetic analyses for physical and metallurgical purposes can be eliminated, without, however, sacrificing loss of accuracy in measurement.

In this connection, outstanding advantages of the balance are as follows :—

(1) When changing from one sample to another, the only adjustment required is that of a counterweight.

(2) Adjustment and calibration of the instrument are comparatively simple. The stability of the apparatus is exceptionally good, so much so that readjustment of its components is unnecessary, even after several days. Only in the case of specially accurate measurements is calibration required for each individual measurement.

(3) Local mechanical disturbances, such as the effect of operation of the rotary pump, have no influence on measurements. Furthermore, the absence of the optical system usually employed in automatic recording systems of this kind eliminates the difficulties generally associated with its use.

(4) Sensitivity can be adjusted to cover samples with widely varying masses.

STEAM TURBINES

Some Practical Effects of Tip Clearance in Turbine Blading.

By J. L. JEFFERSON. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne*, April 23, 1954, pp. 419-474, 30 illustrations.)

THIS paper, after touching on the historical aspect, with a brief reference to the early " Barrier "-type turbine, passes on to a discussion of some of the earlier formulae which have been suggested for finding the effect of tip clearance on the efficiency of turbine blading.

Static tests on the nozzle testing machine at Heaton Works are described and the limitations of this type of test are indicated. Tests on an experimental turbine, arranged for both single-stage and multi-stage arrangements of blading, are described. The effect of the degree of reaction and of ventilating the disc in the case of single-row wheels is illustrated and the effect of clearance over a wide range of incidence is shown on different shapes of profile, both fitted with shrouds and axial clearance, and also plain and thin-tipped radial clearance. In addition, the effect of the leakage fluid in distributing the fluid in the succeeding row is discussed.

The conclusions derived are as follows :—

(1) While the nozzle tester can give rates of fall-off of efficiency with clearance close to those measured in turbines, it is probable that this is really a coincidence, as demonstrated by the results at very large clearances. It can, however, pick out the blades which are likely to be sensitive at the smaller clearances and so yield results of value. The effect of increasing the pressure ratio is to reduce the rate of loss, while the effect of raising the incidence is to increase the rate of loss.

(2) Tests on single-row wheels have suggested that it is difficult to arrange a wheel which will have a high efficiency when not credited with the energy leaving the stage and, at the same time, be insensitive to shroud clearance. In particular, the use of nozzles with low values of efflux angle α, has been shown to be detrimental, and even a high degree of reaction can give a moderate rate of loss when the value of the efflux angle is suitable.

(3) The effect of shrouding in multi-stage turbines is to reduce the rate of loss in blades which are too widely pitched and suffering from high loss due to greater loading. Some of this advantage is lost if the

HUMAN-ENGINEERING ASPECTS OF SAFETY

(*Concluded from page 226*)

and abilities at any given period will depend on a knowledge of the amount of deterioration that normally can be expected at that time. Although compensatory changes of method may appear with age, the difficulty of dealing with new and complex information rapidly militates against older persons from comparatively early ages. These changes may vary greatly from one person to another in both nature and extent, but even minor deteriorations in many of the psychological and physiological functions may interact to produce a significant loss in overall efficiency.

Although all the sense organs of the body show a loss of sensitivity with age, important changes occur in vision. Visual functions, such as accommodation, acuity, depth perception, and dark adaptation are known to be influenced adversely by the ageing process. These changes, however, are of less significance than is frequently supposed and hardly great enough to impair performance, even for an aircraft pilot, until he reaches the age of 50 years or over. The loss in auditory sensitivity occurring with age is rarely sufficient to create an operational hazard.

Insofar as mental ability is concerned, there are definite changes in such functions as ability to learn, memory, reasoning, and judgment, especially in relation to speed or ability to deal with complex factors within given units of time. Compensation takes place for every deviation, however, and if certain capabilities diminish, others are enhanced. Thus, if a fairly profound decline sometimes occurs, compensation and changes in method often result, so that final achievement changes relatively little, or at times may even increase. With regard to undertaking new tasks or duties, various studies show that attitude and incentive are often as important in the end as deterioration in innate capacities.

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blades are worked at low velocity ratio, but shrouding should give greater latitude in the choice of pitch.

(4) With radial-clearance blading, profiles having a large pitch-to-chord ratio can be very sensitive to clearance.

(5) Blades required for traction work should have low loading, as the reduction in torque with clearance can be severe at zero velocity ratio.

(6) The loss due to clearance is not only caused by an increase in quantity but also by a reduction in torque. Since there is still a loss when shrouding is fitted, there are losses present other than the losses due to flow from the " lower " to the " upper " surface of the blade.

(7) Future work should include tests to find the effect of Reynolds number and pressure ratio on clearance loss, and also the most suitable way of expressing the variations of the loading of the blading.

STRENGTH OF MATERIALS

The Ultimate Strength of Aluminium-Alloy Formed Structural Shapes in Compression.

By R. A. NEEDHAM. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 21, No. 4, April 1954, pp. 217-229, 12 illustrations.)

THE primary structure of modern aircraft usually contains many wide, thin plate elements loaded in compression. Thin-walled round, square, and rectangular tubes, and flat or curved sheet, to which are riveted formed or extruded structural shapes are but a few of the examples of this type of construction. These members are analysed as columns.

As the length of a column of compact cross-section decreases, the stress at primary failure increases, and the failure stress is accurately predicted by the Euler equation employing the tangent modulus. If, however, the cross-section of the column is made up of thin plate elements, the stress at failure will be modified by localised plate buckling of these elements. When the column slenderness ratio is large, the stress for general column failure is less than that at which plate buckling takes place, and the Euler equation correctly predicts the failure stress. As the slenderness ratio decreases, a point is reached at which the stress for general column failure and the stress at which a plate element of the column cross-section becomes unstable will be equal. It is at this point that the experimental column curve begins to depart from the theoretical column curve. Failure above this point is an interaction of general and local failure. In the short-column range, failure is due almost entirely to the plate-buckling plenomenon ; in other words, the column strength is not materially affected by length. The stress in this region is variously referred to as the crippling, crushing, or maximum average stress.

In this paper, a new method of predicting the maximum average (crippling) stress of formed sheet-metal structural shapes in compression is presented. The proposed method is based on the assumption that a formed structural shape, consisting of a series of flat plate elements, can be treated as a series of angle sections possessing various degrees of edge support parallel to the direction of loading. A weighted crippling stress of the formed structural shape is obtained by summing the crippling loads of the individual angle sections and dividing this summation by the gross area of the structural shape.

ULTRASONICS

Ultrasonic Liquid-Level Indicator Systems.

By R. L. ROD. (From *Electronics*, Vol. 27, No. 4, April 1954, pp. 156-161, 8 illustrations.)

THE basic requirements of a useful liquid-level gauge are accuracy, reliability, and low cost. Accuracy requirements of $\pm\frac{1}{8}$-in. error in 50 ft are not uncommon in the petroleum industry, where a change of $\frac{1}{4}$-in. in the level of a large storage tank can represent a very considerable quantity of liquid.

This paper describes two sonar-type liquid-level indicating systems, which were designed to eliminate moving parts. One of these is automatically calibrated, to compensate for changes in the speed of sound with temperature and in different liquids. The other incorporates manual calibration facilities, and lends itself to special measurement problems involving liquids of known and stable acoustic characteristics.

Features common to both systems are the complete absence of floats, linkages, potentiometers and similar moving parts, and static capacitance probes ; no direct-current flow is present in or around the tanks concerned or in the coaxial cables forming the only connection between the indicators and the tanks themselves ; alternating-current energy is low, so that the systems are safe for use in explosive tank areas ; and any number of tanks may be gauged economically by a common indicator, which displays level readings directly in tens, units, tenths, and hundredths of a foot.

The indicators may be arranged, if desired, to delivery digital level data to commercially available tape printers, for automatic inventory purposes. These recorders may be located several thousand feet away from the indicators, without requiring special data-transmission accessories. If necessary, the information may be transmitted over much greater distances, by means of conventional wire or radio transmission networks.

These new systems appear to satisfy the need for versatile gauges capable of accelerating the trend to completely automatic process control and inventory, particularly in large refineries and chemical plants.

IMPROVEMENTS IN THE MANUFACTURE OF TRANSFORMER SHEET

(*Concluded from page* 242)

other components, such as stampings, the very high demagnetisation factor and the difficulty created by the necessity for using a coil for magnetisation make this an inefficient method for production purposes.

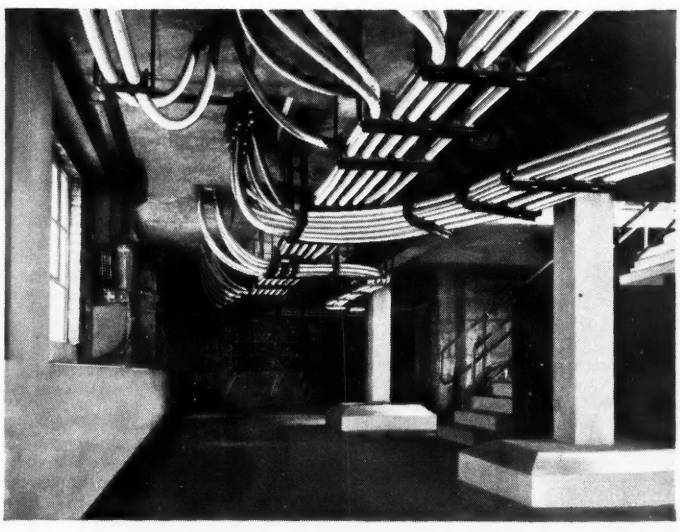
The effect on nickel-iron alloys of cooling in a magnetic field has long been known. A treatment of this kind was investigated by Milner and Kliucharev[40], who found an increase of from 100 to 200% in maximum permeability, as well as a corresponding reduction in the coercive force. No difference was observed between cooling in a constant or in an alternating magnetic field. Goerz[41] found a very pronounced effect on silicon-iron alloys (μ_{max} rising from 55,000 to 215,000), the maximum value being obtained with a silicon content of 6·3%.

The influence of the rate of cooling in a magnetic field was investigated by Grigoluk[42], who found that there is a maximum limit for the rate of cooling, owing to the fact that the material must have sufficient time to equalise the magnetostrictive stresses occurring during cooling. Grigoluk also investigated iron losses as a function of field intensity, and found a reduction of up to 30% for a magnetic induction of 10 kilogausses. Grechov and Glushkova[43] observed on transformer sheets of 0·35 and 0·5 mm in thickness, after annealing at 600 to 750° C, an improvement in permeability and in iron losses resulting from cooling in a magnetic field of 20 oersteds, with a maximum permeability increasing from 6,000 to 16,000. As a result of a preliminary annealing treatment at 1100° C for 6 hours in a hydrogen atmosphere, the maximum permeability in subsequent treatment in a magnetic field was increased to 22,000.

Considerable experience has also been accumulated in Germany with regard to the production of cold-rolled silicon steels, and it will probably be possible in the near future to supply sheet of somewhat greater width, such as those required for large-size transformers.

Cables by EDISWAN

To facilitate increased production of beet sugar at the Kidderminster and Poppleton factories of the British Sugar Corporation Ltd., a complete re-planning of the L.T. power and lighting distribution schemes was recently undertaken. This work, involving the erection and jointing of some 4,000 yards of Ediswan paper-insulated mains cable in each factory, was designed and carried out by the Cable Contracts Department of The Edison Swan Electric Co. Ltd., in association with the Corporation's engineers.



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NEWS OF THE MONTH

PERSONAL

Mr. R. Adams, M.I.Mech.E., has been appointed technical director and general sales manager of the newly formed W.K.M. Valve Co. (Britain) Ltd., 10 Dover Street, London, W.1, which will represent the international interests of the W.K.M. Company, of Houston, Texas, U.S.A.

Mr. A. W. V. Agutter has been appointed a director of Coventry Machine Tool Works Ltd., Halifax. He is President of the British Association of Machine Tool Merchants.

Mr. N. V. Baldwin has been appointed managing director of Brookhirst Igranic S.A. (Pty.) Ltd., 19 Link Road, Langlaagte, Johannesburg, South Africa.

Mr. Rex Bate, M.I.E.E., has been appointed sales director of Enfield Cables Ltd., Victoria House, Southampton Row, London, W.C.1.

Mr. H. W. Bowen, O.B.E., M.I.Mech.E., M.I.P.E., has been appointed technical director of H. J. Baldwin & Co. Ltd., Nottingham, and consulting engineer to the Baldwin Group of Companies.

Mr. S. Bramhall, managing director of Smith's Stamping Works Ltd., Coventry, has been elected chairman of the company.

Sir George Briggs, A.M.I.Mech.E., a director of Tube Investments Ltd. and member of the Royal Ordnance Factories Board, has been elected a director of Brush Group Ltd.

Mr. Lewis Burn, M.I.Mech.E., has joined Armstrong-Whitworth (Metal Industries) Ltd., Close Works, Gateshead-on-Tyne, as engineering consultant.

Mr. W. H. Cartwright has been appointed general manager of Stern & Bell Ltd., Warstock Road, Birmingham, a member of the Triplex Group.

Mr. Victor C. H. Creer, M.A., a director of the British Thomson-Houston Co. Ltd., has been elected chairman of the council of the Electric Lamp Manufacturers' Association.

Mr. Kenneth Croxton has been elected a director of Geo Robson & Co. (Conveyors) Ltd., Eclipse Engineering Works, Hodgson Street, Sheffield 3.

Mr. C. E. Darlington, vice-principal of Halesowen College, Birmingham, has been appointed principal of the Technical College, Gateshead, in succession to **Mr. J. S. Elliott,** who has been appointed principal of Rutherford College of Technology, Newcastle-upon-Tyne.

Mr. R. Ellis, A.M.I.Mech.E., has been appointed manager of British United Traction Ltd., Leyland, Lancashire.

Mr. V. J. Faulkner has been elected chairman, and **Mr. C. H. Alsop,** vice-chairman, of the Publicity Committee of the British Electrical and Allied Manufacturers' Association, 36 and 38 Kingsway, London, W.C.2.

Mr. L. A. Ferney, M.I.Mech.E., has resumed his industrial consulting practice, in which he is associated with **Mr. D. J. Desmond, M.I.E.E.,** and **Mr. A. J. Lucking, A.C.G.I.,** at 93 Westbourne Terrace, London, W.2.

Air Commodore L. R. S. Freestone, O.B.E., A.F.R.Ae.S., who has been Director of Armament Engineering, Air Ministry, since November, 1952, has been appointed Director (Air) of Technical Services, British Joint Services Mission, Washington, D.C., to succeed **Air Commodore C. L. Dann, C.B.E.**

Mr. R. M. W. Grant, B.Sc.(Eng.), M.I.Mech.E., A.M.I.I.A., has been appointed manager of the Transformer Works of The General Electric Co. Ltd., at Witton, Birmingham, in succession to the late Mr. C. H. Nunn.

Mr. R. W. Grice has been appointed chief experimental engineer for cars and commercial vehicles to the Austin Motor Co. Ltd., Longbridge, Birmingham.

Mr. J. M. Griffiths has been appointed manager of the centrifugal purifier department of Hopkinsons Ltd., Huddersfield, in succession to **Mr. A. R. Sutcliffe.**

Mr. L. H. Griffiths, M.Sc., F.R.I.C., technical manager of Semtex Ltd., Semtex House, Broadway, London, N.W.9, has been appointed assistant general manager. **Mr. Walter Saul,** works manager of the Semtex Castle Bromwich factory, has been appointed to succeed Mr. Griffiths as technical manager of the company.

Mr. P. W. Grigsby has been appointed production manager of the de Havilland aircraft factory at Hatfield, Hertfordshire.

Mr. A. E. Grimsdale, B.Sc.(Eng.), has been appointed a director of Metropolitan-Vickers Electrical Export Co. Ltd., 1/3 St. Paul's Church Yard, London, E.C.4.

Captain (E) H. J. B. Grylls, A.D.C., R.N., has been promoted to Rear-Admiral and appointed engineer manager of the Devonport Dockyard, in succession to **Rear-Admiral C. R. P. Bennett, C.B.E.**

Lieut-Colonel Claud Hardie has resigned from his position of joint managing director of Tyer & Co. Ltd., and B.P. and Tyer's Signals Ltd., Ashwin Street, London, E.8, but will continue as technical director of both companies. **Mr. D. S. Bennett,** managing director of both companies, has been elected to the Boards of P.A.M. Ltd., Guildford, and Resinoid and Mica Products Ltd., Balsall Heath, Birmingham 12.

Mr. L. C. Hoare has been appointed manager of the Purchasing Department of Shell-Mex and B.P. Ltd., Shell-Mex House, Strand, London, W.C.2.

Commander (E) L. J. F. Howard-Mercer, M.I.Mech.E., M.I.Mar.E., M.I.N.A., R.N.(Ret)., has been appointed assistant to Mr. J. T. MacLeod, managing director of H. Widdop & Co. Ltd., Keighley, Yorkshire.

Mr. A. L. Hunking, managing director of Westool Ltd., St. Helen's Trading Estate, Bishop Auckland, has been elected chairman of the Tees-side District Advisory Committee of the Northern Regional Board of Industry.

Commander C. M. Jacob, D.Sc., A.M.I.E.E., R.N.(retd.), has been appointed deputy technical manager of Marconi International Marine Communication Co. Ltd., Chelmsford, Essex.

Mr. S. R. Kilner, Dipl.Eng., M.I.Mech.E., works and technical director of S. N. Bridges & Co. Ltd., Parsons Green Lane, London, S.W.6, has been elected to the Board of the company, which is a member of the John Brown Group.

Mr. E. A. King has been appointed general sales manager of Taylor, Taylor & Hobson Ltd., Leicester.

Mr. E. J. Leaver has been appointed manager of the Carron Company, Carron, Falkirk, Scotland.

Mr. John Lonsdale, M.I.P.E., works manager of Sanderson Brothers & Newbould Ltd., Newhall Road, Sheffield, has been elected to the Board of the company.

Mr. H. G. McKerrow has been appointed a director and chief consulting engineer to the Anglo American Corporation of South Africa Ltd., 11 Old Jewry, London, E.C.2.

Mr. J. S. Makin has been appointed branch manager of the Manchester office of British Insulated Callender's Cables Ltd.

Mr. C. V. Miller, sales manager of Nu-Way Heating Plants Ltd., Droitwich, has been elected a director of the company.

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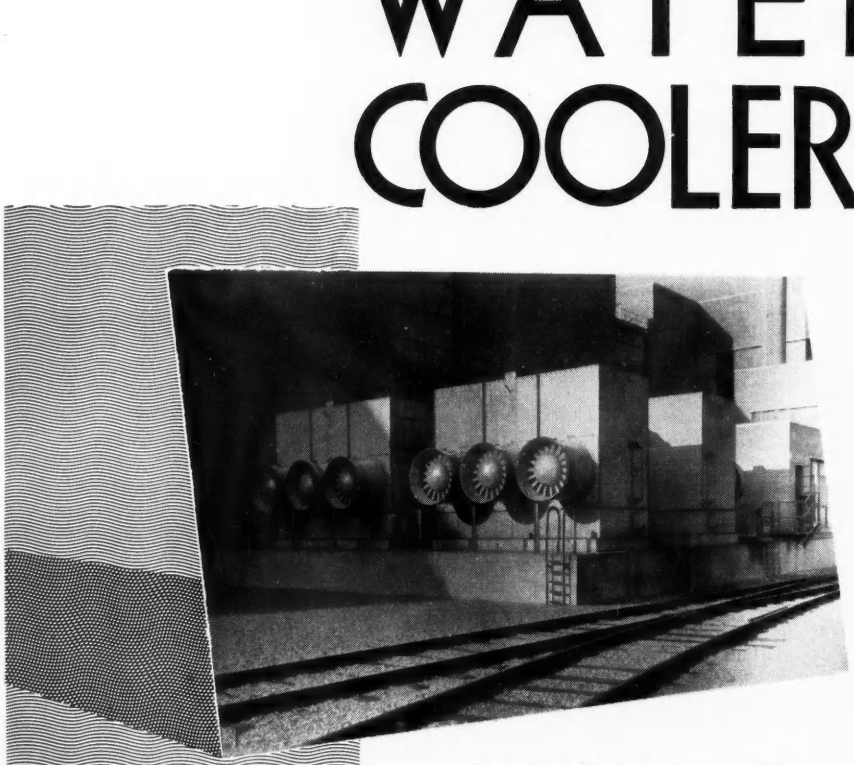

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Mr. J. C. Milne, M.I.E.E., A.Amer.I.E.E., has been elected to the Board as technical director of the Electric Construction Co. Ltd., Bushbury Engineering Works, Wolverhampton.

Mr. T. E. Parkinson, formerly sales manager of Sykes Machine Tool Co. Ltd., has joined the Mortimer Engineering Co. Ltd., 210 Acton Lane, London, N.W.10, as sales manager.

Mr. J. Plowman, Scottish general manager of Dewrance & Co. Ltd., has been appointed chief executive assistant to the managing director at the London head office. **Mr. D. Handley** has been appointed manager of the Dumbarton Works of the company.

Mr. G. B. G. Potter, M.I.Mech.E., managing director of Kelvin & Hughes Ltd., has been appointed to the Board of the parent company, S. Smith & Sons (England) Ltd.

Mr. R. T. Priestman has been elected President of the Aluminium Development Association, in succession to **Mr. R. D. Hamer,** who has now been elected vice-president. **Mr. Harold Goodwin** has been elected chairman of the executive committee, in succession to **Mr. G. W. Lacey.**

Sir Walter Puckey, M.I.Prod.E., F.I.I.A., has been re-elected President of The Institution of Production Engineers, 10 Chesterfield Street, London, W.1. **Mr. G. Ronald Pryor,** chairman and managing director of Edward Pryor & Son Ltd., Sheffield, has been elected Chairman of the Council. **Mr. H. G. Gregory,** manager of the Northern factories of the Fairey Aviation Co. Ltd., Stockport, has been elected vice-chairman of the Council.

Mr. A. P. Quarrell, A.M.I.Mech.E., A.M.I.Mar.E., has been elected chairman of British Oil Engines (Australasia) Pty. Ltd. and has been appointed managing director of Brush Electrical (Australia) Pty. Ltd. **Mr. J. E. Cestell** has been appointed managing director of British Oil Engines (Australasia) Pty. Ltd.

Mr. S. A. Roberts, who became general manager of the B.S.A. Tools Group in 1953, has now been appointed to the Boards of B.S.A. Tools Ltd., Leo C. Steinle Ltd., and Cardiff Foundry & Engineering Co. (1947) Ltd.

Mr. S. Rymell has been appointed deputy chief inspector of Folland Aircraft Ltd., Hamble, Southampton. **Mr. E. H. S. Folland** is chief inspector of the company.

Mr. L. H. G. Sterne has been promoted to the rank of deputy chief scientific officer and has been apppointed Head of the Naval Air Department of the Royal Aircraft Establishment, Farnborough.

Mr. M. E. O'K. Trowbridge, B.Sc., A.C.G.I., A.M.I.Chem.E., has been appointed general sales manager of Sharples Centrifuges Ltd., Woodchester, Stroud, Glos.

Mr. G. R. Tyler has been appointed manager of the newly formed Maritime Division of Marconi's Wireless Telegraph Co. Ltd., 336 Strand, London, W.C.2. **Mr. J. Watt** has been appointed chief engineer of this division. **Mr. R. H. Deighton** has been appointed manager of the Central Division. **Mr. H. J. H. Wassell** has been appointed chief engineer of the Radar Division. **Mr. R. E. Burnett** has been appointed assistant to the general manager of the Company. **Mr. E. R. L. Lewis** has been appointed deputy manager, education and technical personnel, **Mr. R. G. Hulse,** deputy principal of Marconi College and director of Studies, and **Mr. J. Lindsay Scott,** chief of technical personnel recruitment.

Sir Cullum Welch, O.B.E., M.C., has been elected to the Board of C. C. Wakefield & Co. Ltd., 46 Grosvenor Street, London, W.1. Sir Cullum succeeds **Mr. Holland Young Blades** who has resigned after 55 years' service to the company.

PRODUCTION FOR PLENTY

Britain's first Production Exhibition, which is to be held in the National Hall, Olympia, London, from the 7th to 14th July, 1954, has aroused widespread interest both at home and abroad.

The British Productivity Council's exhibit will introduce the theme of the Exhibition—"Production for Plenty"—explaining what is meant by productivity and how vital is the question of increased production to the welfare of the community.

The central avenue of the Exhibition is devoted to Research and Development and will contain a large-scale exhibit from the Department of Scientific and Industrial Research, showing the work of Research Associations in a wide field of industries. The British Standards Institution will be illustrating the importance of standardisation, simplification and safety, and there will be other exhibits by industrial research organisations.

The Ministries of Labour and Education and certain Institutions intend to demonstrate the importance of human relationship and the training of management, technologists, and skilled labour. There will be a special section devoted to vocational guidance.

Next to the central research avenue will come those organisations who intend to show examples of work study, production control, planning and production methods.

Displays by Government Departments will include exhibits from the Ministries of Fuel & Power, Supply, Works, the Board of Trade. The British Transport Commission are also exhibiting.

There will be displays of production engineering research, industrial finishing, precision casting, instrumentation, weighing and measuring equipment, induction heating, refrigeration as applied to industry, and other processes which contribute to improved productivity. Supplementary services, such as electrical developments, transport, lubrication, scientific instruments, high speed cinematography, the X-ray examination of metals, developments in production related to basic materials and metals, and "Aids to Production" such as lighting and colour in the factory, will be represented.

1955 BRITISH INSTRUMENT INDUSTRIES' EXHIBITION

Next year's B.I.I. Exhibition will be held in Earls Court, London, from June 28th to July 9th, 1955. It will cover all spheres of instrumentation in pure and applied science. It will embrace temperature, pressure and flow controllers; navigation equipment, medical instruments, industrial photography and all instruments used in scientific research.

The Exhibition is sponsored by the British Electrical and Allied Manufacturers' Association, the British Industrial Measuring and Control Apparatus Manufacturers' Association, the British Lampblown Scientific Glassware Manufacturers' Association, the Drawing Office Material Manufacturers' and Dealers' Association, and the Scientific Instrument Manufacturers' Association of Gt. Britain.

The Organizers are F. W. Bridges & Sons Ltd., Grand Buildings, Trafalgar Square, London, W.C.2. Spottiswoode Dixon & Hunting Ltd., Bedford Row, London, W.C.1, are the advertising agents.

HEAVY METAL FOR AIRCRAFT

In aircraft construction, where the emphasis is always on lightness, increased use is being made of small quantities of a metal which is specifically intended to be as heavy as possible.

A heavy metal can, paradoxically, achieve lightness in the long run, because it enables designers to concentrate weight in a small space; lighter material calls for a larger structure—and hence more weight.

A special heavy alloy for aircraft, produced by the General Electric Company, is used for mass-balances for control surfaces—ailerons, and elevators, and for other small but important parts of aircraft, such as wheel brakes, instruments, and even aircraft cameras.

For the future, G.E.C. have under development a high-density alloy which will be manufactured in sheet form—though the size of sheet available will be very limited.

The main constituent of heavy alloy is tungsten powder. This, mixed with nickel and other powders, is placed in a die and compressed to shape. It is put in an electric furnace in a hydrogen atmosphere at a white-heat temperature of about 1450 deg. C. While in the furnace it shrinks by about one-fifth.

The alloy can then be given any of the usual plated finishes.

BRITISH IRON AND STEEL FEDERATION

Under the auspices of the British Iron and Steel Federation, a programme of short films was screened at the British Council Theatre on May 27. Of these, "Blister Steel" is an excellently produced and photographed 10-minute record of the cementation process—a graphic illustration of an extinct industry, of interest to technical and non-technical audiences as a historical document.

Another film, "The Formation of Bainite," issued by the British Iron and Steel Research Association, explains by means of diagrams the essential structures which form during the heat treatment of

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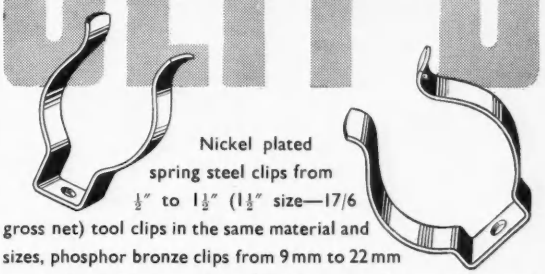

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steel, and shows the actual formation of martensite and bainite in steel specimens at high temperatures under a "hot-stage" microscope.

Other films included the amusing and imaginatively conceived colour cartoon, "The House That Jack Built," which is a reasoned appeal for the recovery of scrap metal, and a selection of black-and-white, colour, and stereoscopic sequences illustrating various laboratory investigations and techniques.

Open-Hearth Flame and Output will be the theme of a one-day conference to be held in the Institution of Engineers and Shipbuilders in Scotland, 39 Elmbank Crescent, Glasgow, C.2, on September 10th, 1954. The programme is as follows:—

10.00 a.m. Group I:
- "Combustion and Radiation Characteristics of Oil and Coke-Oven Gas Jet Flames," by Prof. M. W. Thring, M.A. (Sheffield University).
- "Melting Rates in the Open-Hearth Furnace," by E. J. Burton (British Iron and Steel Research Association).

11.30 a.m. Group II:
- "Improvements in Firing Oil and Coke-Oven Gas in the Open-Hearth Furnace," by J. A. Leys, B.Sc. (British Iron and Steel Research Association).
- "Making Producer Gas a Competitive Fuel," by G. W. C. Allan, B.Sc., Ph.D. (British Coal Utilization Research Association).
- "The Use of Various Fuels in the Open-Hearth," by W. B. Wright (Colvilles Ltd.).

2.15 p.m. Discussion to be opened by Mr. R. W. Evans (Steel Co. of Wales), chairman of the Steel Practice Committee, British Iron & Steel Research Association.

The conference will end about 4.45 p.m.

MOND NICKEL COMPANY LIMITED

To demonstrate its versatility, an exhibition of Spheroidal Graphite Cast Iron was held at Park Lane House between May 25 and May 27, by the Mond Nickel Company Limited.

Exhibits included such widely varying items as pump bodies for compressors, pistons, crankshafts, rotary-pump impellers, heavy-duty switchgear links, chuck bodies, hoist blocks, pneumatic-type moulds, bar-mill finishing rolls, propellers, valves, gear cases, pulleys, and face plates for lathes.

BROOK MOTORS LIMITED

To mark their Jubilee celebrations, Brook Motors Limited, of Huddersfield, have published a commemorative 328-page volume, entitled "Alternating Current Electric Motors." The history of the firm is given in a supplement at the beginning, the rest of the book being devoted to technical information of real value to electrical and plant-maintenance engineers. The latter section of the book is naturally its main attraction and, if the demand warrants it, further editions may be printed of this text-book section only.

The book is very well produced and lavishly illustrated. A useful index is also included. Its normal price is 15/-, but it is supplied free to customers.

THOMAS DE LA RUE & CO. LIMITED

The Tynemouth factory of Thomas de la Rue & Co. Limited, which the Technical Press recently had an opportunity of visiting, was opened in September 1947 and is the largest laminated plastics factory in Europe, specialising in the manufacture of Formica, Delaron, and Traffolyte. Other types of plastic made at this factory are extrusions and P.V.C. sheeting.

Formica has a very wide range of domestic and industrial applications where, by virtue of its resistance to abrasion, its hardness, and its ease of cleaning, it provides a near-permanent solution to many decorative problems on walls, table-tops, etc. Delaron is the non-decorative form of Formica; the paper-based type has outstanding electrical insulating properties, while the fabric-based type possesses outstanding mechanical properties, which make it eminently suitable for applications, such as gear wheels, where rugged performance, low weight, and silent operation are required. Like Formica, Traffolyte is a decorative laminate, but its resistance to abrasion and its range of colours are less than those of Formica. It is, however, less expensive, and is much in favour for ceilings, where its extreme ease of cleaning and freedom from maintenance costs are notable.

BUSINESS NOTES

The Distillers Company Ltd. has moved most divisions and subsidiary companies in its industrial group to Devonshire House, Mayfair Place, London, W.1. Tel. No. MAYfair 8867. Following these changes, **Magnesium Elektron Ltd.** has moved to Distillers House, 20/21, St. James's Square, London, S.W.1. Tel. No. WHItehall 1040.

Percival Aircraft Ltd., Luton Airport, Bedfordshire, have changed the name of the company to Hunting Percival Aircraft Ltd.

Sheepbridge Steel Castings Ltd., Sutton-in-Ashfield, Nottinghamshire, has changed the name of the company to Sheepbridge Alloy Castings Ltd. A new bronze foundry is being developed for the production of special non-ferrous alloys. Another new development is the production of long length tubes centrifugally cast in special metals.

"Copper for Busbars." This informative publication, which has been out of print for some time, is again available, free, on application to the Copper Development Association, Kendals Hall, Radlett, Herts.

Minnesota Mining and Manufacturing Co. Ltd., Adderley Park, Birmingham 8, announce the opening of a sales office at 90 Mitchell Street, Glasgow C.1. Telephone: City 6704/5.

Rudkin & Riley Ltd., Aylestone, Leicester, have been appointed sole distributors at home and overseas of the wire drawing die profiloscopes manufactured by Longworth Scientific Instrument Co. Ltd. and designed by the British Iron and Steel Research Association.

The Alexander S. Newall Machine Tool Co. Ltd. have recently opened their new showrooms at 162 Finchley Road, London, N.W.3 (Tel. No. HAMpstead 3855), opposite their head office. The new showrooms are intended as a permanent exhibition of Roch-Etalon precision measuring instruments, Wolferal cutting tools, Kelch-Ortlieb arbors, chucks and collets, and other small tools.

"Wiggin Nickel Alloys—26." The leading articles in the latest issue deals, in some detail, with the operating experience obtained with Nimonic Alloys in de Havilland Ghost engines. On an average it is stated that three turbine blades are changed on each time-expired engine during its overhaul, in every case due to damage caused by extraneous matter passing through. In no case has it been due to the effect of fatigue or thermal stress on the Nimonic Alloys which are standard for this application.

A further article shows the use of these materials in the Pratt & Whitney J-42 Turbo-Wasp, the American equivalent of the Rolls-Royce Nene gas turbine. Other articles deal with the Bristol Instrument Company's use of Monel in their convertible thermometer bulbs and of the use of this corrosion-resistant alloy to protect steel piling exposed to sea-water attack. Another example of the successful use of this alloy is for a "Solution Reboiler" used in the removal of hydrogen sulphide in the amine treating process. The shell and channel are fabricated from Monel-clad steel and contain 492 Monel tubes supported by plates and tie rods also of Monel which is used for all other internal components.

An interesting detailed account is given of the Free Pendulum Astronomical Regulator made by the Synchronome Company Ltd. In this system Nilo 36, a special nickel-iron alloy with a very low coefficient of expansion, is used for the slave pendulum and for the bob of the controlling pendulum. A free pendulum at the Paris Observatory has run for nearly two years without discoverable error.

Copies of "Wiggin Nickel Alloys" may be obtained free of charge on application to the Publications Department of Henry Wiggin & Co. Ltd., Thames House, Millbank, London, S.W.1.

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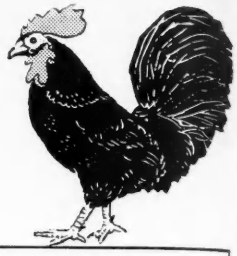

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The Financial Times Annual Review of British Industry, to be published on June 18th at the price of 1/–, is the result of an ambitious and praiseworthy project. Whilst, admittedly, it is impossible to survey the whole field of British Industry in the 49 articles of this issue, the more important aspects and trends of British economy are discussed nevertheless in a concise and authoritative manner.

In addition to articles dealing with problems of commerce and finance, insurance, agriculture and horticulture, smoking and drinking, housing and building, architecture and civil engineering, there are a number of excellent articles of more direct concern to engineers and the engineering industries. Amongst these latter contributions we wish to draw attention to the following articles :— Coal : The Precarious Balance, by S. W. Parkinson ; Demand for Steel, by Aubrey Jones, M.P., Economic Director of the British Iron and Steel Federation ; Stability in the Chemical Industry, by W. J. Worboys, chairman of the Association of British Chemical Manufacturers ; New Oil Refineries—New Patterns of Demand ; The Search for more Efficient Power, by G. N. Critchley ; Better Power Stations ; Achievements and Problems in Aircraft ; Competition for Shipbuilders, by J. W. Elliott, President of the Shipbuilding Conference ; Machine Tools and the Budget, by Peter Cartwright ; Capacity Output of Diesel Locomotives, by Brian Reed ; Motor Industry in Good Shape, by Dudley Noble ; Adapting Electronics to Peace, by Sir Robert Watson-Watt ; More Drive for Gas Turbines, by Patrick Johnson ; By-Products of Atomic Energy, by W. P. Grove ; The Shortage of Scientific Manpower, by Professor F. E. Simon ; High Productivity in the Cement Industry, by A. W. Todd ; Britain's Place in the Air, by Peter G. Masefield, chief executive of British European Airways ; Railways and the new Transport Act, by Sir Eustace Missenden ; and The Major Markets for Plastics, by Philip Morgan.

BRITISH ELECTRICAL POWER CONVENTION

Consulting Engineers and Overseas Trade

The functions of the consulting engineer and the contribution he can make to the promotion of electrical development at home and overseas, was the theme of the Presidential Address of Mr. J. R. Beard, C.B.E., M.Sc., M.I.C.E., M.I.E.E., F.A.I.E.E., in opening the sixth British Electrical Power Convention at Eastbourne on Tuesday, 15th June. Mr. Beard recalled that three of his predecessors as President were concerned with electricity supply and two with manufacturing. In choosing him as President his fellow consulting engineers welcomed this public recognition of a profession which, by tradition, had " its light so much hidden under a bushel."

Two requirements of professional practice in this country had always been that consulting engineers should not advertise and that they should not solicit professional work. Such restrictions were not universally applicable or observed in many other parts of the world nor, in many countries, was consulting work entirely divorced from connections with the contracting side. While hitherto this had not been of great importance there is no doubt that at the present day it often tended to affect adversely British overseas trade, particularly in those under-developed countries which had relatively recently acquired control of their own affairs.

The large firms of consulting engineers could be most helpful to this country in the expansion of its oversea trade and influence. The fees earned from overseas work were a valuable invisible export. Consulting engineers constituted the spearhead of the engineering export trade.

Mr. Beard mentioned a development of considerable concern to this country—the practice which had developed in the United States, Asia and Europe of " turnkey " or " all-in " bids for complete projects. A " turnkey " bid, as this American expression implied, was an offer to design and complete a project lock stock and barrel at a more or less lump sum price. Thus it was a comprehensive " all-in " offer covering consulting services, manufacture and construction. At the urgent request of the Board of Trade, very careful consideration was at present being given to arrangements whereby British consulting engineers could assist groups of British contractors to put forward comprehensive offers in competition with those obtainable from abroad.

Atomic Power by Mid-1956

" Sooner than many people dared hope—by mid-1956—the Sellafield atomic power station should be ready for running-up and testing. After another few months the first atomic power station should be supplying electricity to the arterial network of Britain." This forecast was made by Sir George Nelson, chairman and managing director, English Electric Company, in a paper on " Electrical Engineering in World Trade " presented to the British Electrical Power Convention.

Dealing with the impact of atomic energy on electrical engineering, Sir George stated that they must master a new technique. Certain branches of nuclear physics and reactor theory had to be brought to complete economically with the costs of power from normal fuels.

" The engineer and the industry," he said, " must learn to use and handle new materials, to add liquid sodium and heavy water, and a host of others to copper and iron as ordinary engineering materials and we must learn to think of neutron economy as familiarly as of power factor. We must and will create a new engineering within electrical engineering. The process will be difficult and will not be complete in the lifetime of those of us who start it, but it is within our power and a part of our duty. The uneven distribution of fuel in the world and its rising cost make it absolutely necessary that we take this opportunity. It will not replace the normal fuels to the disadvantage of those people employed in the coal mining and oil industries, but will enable those industries to make still greater use of their component elements, compounds and materials for the benefit of man.

" The ability which atomic power gives us to bring energy to areas of the world with little fuel or water provides the opportunity and need to examine the factors which determine the location of industry. As a result, we may confidently expect changes in our present philosophy and considerable changes in the industrial pattern of the world."

Discussing the Sellafield power station Sir George said :— " This prototype installation of the atomic station of the future, will serve as a training ground for those commercial firms who will take over the design and construction of further nuclear power stations, and so fit themselves not only to supply the British Electricity Authority but also other countries with atomic power plant.

Domestic Heat-pump Soon

A dual-purpose heat pump—to provide hot water and a refrigerated larder—will soon be on the market. This was stated by Dame Caroline Haslett, D.B.E., J.P., Comp.I.E.E., director of the Electrical Association for Women, in a paper on " Electricity in the Modern Home."

Dame Caroline said that the Electrical Research Association was concentrating on the economic uses of the heat pump as a domestic installation. With a properly designed unit the running costs for space heating should be one-third of those normally required for electric heating and about half the cost of an electric water heating system using an immersion heater.

Some of the laboratory research had the benefit of trials that were going on in different parts of the country under actual working conditions. A special unit to provide a hot water supply and a refrigerated larder in an average household was tested in the houses of staff at the South-Western Electricity Board, and at Electricity House, Bristol, consisted of an evaporator of domestic type in the larder and a refrigerator compressor unit and condenser coil, the compressor unit and condenser being hermetically sealed and placed in a 30-gallon tank immediately above the larder and below the cold water supply tank in the roof space. Connections were made both to the hot and the cold water supply.

Satisfaction with hot water supply and larder cooling was expressed, and the conclusion was drawn that it would be to everyone's interests—manufacturers, consumers and Area Boards—for progress to be made with manufacture and sale of such dual-purpose units, for there would appear to be a greater demand than for refrigerators alone.

Householders would obtain two appliances in one, and the Area Boards would obtain the highest load factor appliance so far used by domestic consumers.

" Some manufacturers have already experimented with prototypes," said Dame Caroline, " and it is expected that this dual-purpose unit will soon be on the market. These will be in the form of complete ' packaged ' units to be installed in the larder, with pipe connections to the hot water storage tank."

Good Lighting Increases Production

" For the price of a pair of overalls, 100 sq. ft. of factory space can be lighted for 12 months to a level of 20 lumens/sq. ft." This was stated by Mr. W. J. Jones, M.Sc., M.I.E.E., director of the Electric Lamp Manufacturers Association in a paper on " Lighting for Commerce, Industry and the Home."

" During the war and for some time past, attention has been fixed, primarily, on the need for increased production," said Mr. Jones. This increased production has been obtained with the minimum of capital expenditure. Today stress is laid upon more economic and efficient production in order to reduce costs and to be more competitive.

One investigation carried out by the Lighting Service Bureau in a rayon mill showed that increasing the illumination and rearranging the lighting resulted in a 10 per cent. gain of loom efficiency ; the value of the increased production was sufficient to pay for the cost of the lighting 13½ times over. In addition the weaver who was on " piece-work " earned an average of 3/4d. per loom more per week.

In another, the illumination on a lace making machine was increased 3 to 7 times (according to the position on the machine) and as a result the average length of mend was reduced by 38% with an estimated saving of 28% in mending time.

Lighting involves much more than locating light sources symmetrically to produce a general level of illumination. The engineer must consider the task and the surrounds and plan the brightness levels in such a way that seeing is done with the minimum of effort.

An example of the influence which background brightness can have on seeing is shown by the better visibility of the detail in a black object when viewed against a dark background than when seen against a light background—the results being quite contrary to the layman's expectation. Modern lighting is well within the ability of industry to afford, especially when the benefits in production, safety and welfare of the operatives are considered.

Two recent developments in light sources are typical of the manufacturers' constant endeavours to incorporate every possible improvement in their products.

The MBF/U lamp which comprises a high pressure mercury vapour discharge tube with a fluorescent coating on the inside of the outer glass has recently been improved by the use of a new fluorescent powder so that the lamp gives a whitish light with quite good colour rendering. The most important change is in the red emission which has been increased from 5% to 7½%. This lamp which now has a smaller glass bulb will be particularly useful in those locations in industry where close control or a small size of light source is required.

The other development is that of the 1 kW and 2½ kW high pressure, mercury vapour lamps which are particularly suitable for use in lofty factories. Optical control of the light from these high

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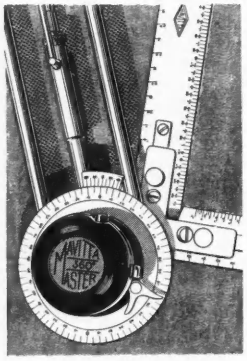

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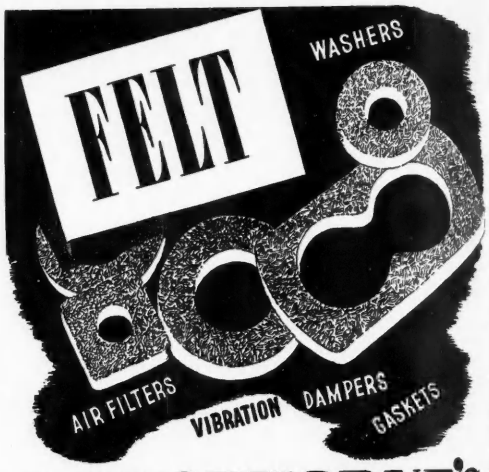

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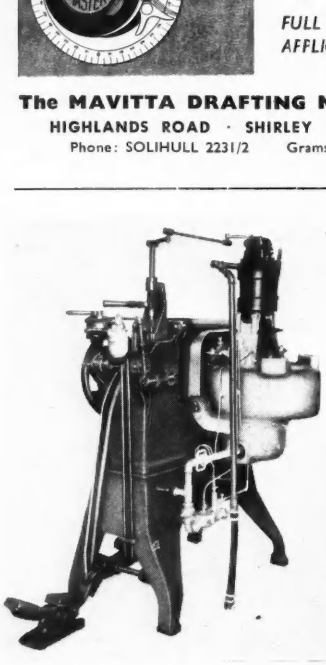

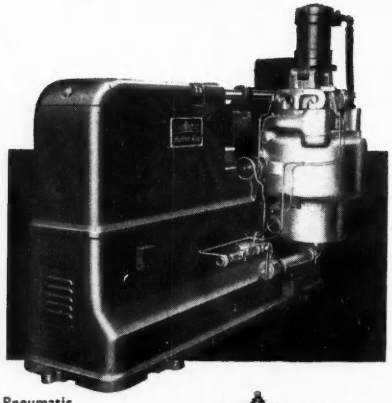

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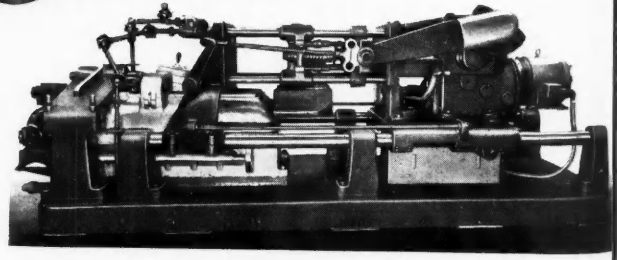

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power lamps makes it possible to light large areas from heights of 80 feet economically to levels of 30 or more Lumens/sq. ft.

Developing Domestic Use of Electricity

Mr. Dennis Bellamy, O.B.E., D.L., chairman of the Yorkshire Electricity Board, was speaking on "The Development of the Domestic Electricity Load at Home and Overseas."

"The availability of electricity supply for homes is an absolute necessity," said Mr. Bellamy, "and greater use of it is both economic and profitable for the consumer and supply authority alike. The development of electricity supply is a great factor in the standard of living and increased productivity of the country."

Mr. Bellamy said that the first and most important requirement for the creation of a higher overall electricity load factor was a wide diversity of demand. As more and more consumers with their varying classes and habits were added, greater opportunities arose for improving diversity. The second important requirement for the development of high load factor was the encouragement of additional use over extended hours.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2, Park Street, London, W.1.)

Chilled Iron Shot & Grit. B.S. 2451 : 1954 is to assist in overcoming the difficulties in obtaining uniform grades and sizes of chilled iron shot and grit for use in shot blasting and kindred applications.

The main object in preparing the standard has, therefore, been concerned with the separation and sizing of the chilled shot and grit and designating grade and size numbers. It also includes requirements for hardness.

The Institution desires to point out that the term "steel shot and grit," which is commonly used in certain sections of the trade, is a misnomer and strongly recommends that its use be discontinued. The correct term is "chilled iron shot and grit."

The grades and sizes of chilled iron shot and grit covered by this standard have been designated 7, 8, 9, 10, 12, 15, 18, 22, 30 and 40.

Screen sizes and tolerances are given to determine the particle size. Price 2/-.

Glossary of Terms Relating to Iron and Steel. B.S. 2094 : 1954 contains the following six parts :—

Part 1 : 1954 "General metallurgical, heat treatment and testing terms."
Part 2 : 1954 "Steel making."
Part 3 : 1954 "Hot rolled steel products (excluding sheet, strip and tubes)."
Part 4 : 1954 "Steel sheet and strip."
Part 5 : 1954 "Bright steel bar and steel wire."
Part 6 : 1954 "Forgings and drop forgings."

The Glossary has been prepared to establish as far as possible uniformity in the interpretation of the numerous terms in current use.

The scope has been limited to those terms in general use in the different producing sections of the iron and steel industry. Terms dealing with the various applications of iron and steel products e.g. in welding and electrical engineering are covered in other British Standard glossaries. Price 6/- for Part 1 and 2/6 each for Parts 2-6.

Olive, Soldered Nipple and Flared Types of Copper and Copper Alloy Tube Fittings for Engineering Purposes. B.S. 2051. Pt. 2 : 1954 provides for the complete dimensional standardization of the copper tube fittings known as olive, soldered nipple, flared and inverted flared fittings for use with copper and copper alloy and other suitable tube designated by its fractional o.d. size for a wide range of engineering purposes and covers the following classes and ranges of fittings :—

(a) Olive fittings of sizes ranging from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. inclusive.
(b) Soldered nipple fittings of sizes ranging from $\frac{1}{8}$ in. to $\frac{3}{4}$ in. inclusive.
(c) Flared fittings of sizes ranging from $\frac{1}{4}$ in. to 1 in. inclusive.
(d) Inverted flared fittings of sizes ranging from $\frac{1}{4}$ in. to $\frac{3}{4}$ in. inclusive.

These fittings are provided with "B.S.P. Whitworth" threads to B.S. 84 or Unified threads to B.S. 1580. Material requirements and tests for porosity are specified, and also details of the maximum working pressures for these fittings.

Illustrations of the fittings together with Tables of Dimensions of each type of fitting are included. Price 12/6.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word ; in bold print 9d. per word ; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

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The inclusive fee for the course of study is £71 1s. 0d. In certain cases where a student is not sponsored by an employer, the University may consider applications for the remission of this fee and, where essential, for the grant of a maintenance allowance during the period of attendance.

Further particulars and application forms may be obtained from the Registrar, The University, Edgbaston, Birmingham, 15.

SITUATIONS VACANT

ARMSTRONG SIDDELEY MOTORS LIMITED, have vacancies for Technical Assistants for research and experimental work on aircraft gas turbines ; particularly on compressors, turbines and aerodynamic flow problems. Engineering Degree, HNC or equivalent necessary. Write in detail to Reference GWB, Personnel Manager, **Armstrong Siddeley Motors Ltd.,** Coventry.

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PATENTS

The proprietors of British Patent No. 599283 for "Suspension Shaft for Rotary Crusher" are prepared to enter into negotiations for the SALE or for the grant of LICENCES thereunder. Enquiries to be addressed to **Carpmaels & Ransford,** 24 Southampton Buildings, Chancery Lane, London, W.C.2.

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RECONDITIONED EX-ARMY HUTS, and manufactured buildings. Timber, Asbestos, Nissen Type, Hall Type, etc. All sizes and prices. Write, call or telephone—**Universal Supplies (Belvedere) Ltd.,** Dept. 50, Crabtree Manorway, Belvedere, Kent. Tel.: ERITH 2948.

WANTED.—Copies of the March, 1953, issue of "The Engineers' Digest" urgently required. Also Jan., 1949, June, 1950, and Dec., 1951, issues at 3/6 per copy.—Subscription Dept., 120, Wigmore Street, London, W.1.

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BOOKS RECEIVED

British Plastics Year Book, 1954. 24th Edition. 600 pp. Publishers: Iliffe & Sons Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 30/- (postage 1/3).

Revised and expanded, this new edition of the British Plastics Year Book remains the only classified guide to products and manufacturers in the plastics industry. It is divided into nine sections, of which three are devoted to classified lists of manufacturers and suppliers of materials, finished products, and equipment. Another section contains the world's largest list of trade and proprietary names connected with the plastics industry, and covers materials as well as finished products. Each trade name is followed by a definition of the product, the manufacturer concerned, the country of origin, etc. A glossary of technical terms used in the plastics industry is included in this section.

The names-and-addresses section covers nearly 4000 firms associated with plastics, both in Great Britain and abroad, and, for the first time, these names are grouped into countries. In addition, there is a " Who's-Who " section, listing names and positions of prominent people in Britain's plastics industry.

An important feature is the annual review of plastics patents, covering 117 pages. In addition, new plastics companies are listed, together with their official dates of registration, addresses, activities, capital, and directors.

A general index has been added, enabling quick reference to be made to any product or subject in the book.

Mechanical Testing of Metallic Materials. 3rd Edition, 1954. By R. A. Beaumont, A.M.I.Mech.E., A.F.R.Ae.S. 262 pp., 151 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 25/-.

Based upon lectures and practical demonstrations given by the author at the Mechanical Testing Laboratory of the College of Aeronautical Engineering, this new edition has been completely revised and partially re-written, so as to bring it up to date.

The subject of proof stress is specially dealt with, and details are given of an entirely new and unique method which has been evolved in recent years. Extensometers and recorders provide another new chapter, in which particulars are given of high-magnification, autographic stress/strain recorders developed in Great Britain and the United States. Also, in view of the importance of creep testing, this specialised aspect of tensile testing has been added to this new edition, which should be of undoubted value to all aeronautical and engineering students.

Characteristics and Applications of Resistance Strain Gages. National Bureau of Standards Circular No. 528, issued February 15, 1954. 140 pp., 143 illustrations. For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington 25, D.C. Price: $1.50.

This publication contains the proceedings of the NBS semi-centennial symposium on resistance strain gauges, held on November 8 and 9, 1951. The papers presented at this symposium represent some of the latest results, both experimental and theoretical, in the study of resistance strain gauges by many leading institutions in the United States and abroad.

Though these gauges are a comparatively new tool in the study of materials and structures, they are finding consistently wider use. They have been employed in the measurement of mechanical quantities, such as acceleration, impact force, and dynamic pressure; they have been applied as the sensing element in a multitude of instruments, and have been used to determine strain distribution in a wide range of structures, from aircraft wings to bridges.

The papers presented covered these applications and also reported new work in progress on strain gauges consisting of a conducting coating applied by an evaporation technique, on special temperature-compensated gauges, on gauges for strain measurements well beyond the elastic range, and on the application of strain gauges to the determination of dynamic properties of materials and to the measurement of very large static forces. Eleven papers are reported in this volume, together with transcriptions of the discussions which followed.

Aufwand, Leistung und Wirtschaftlichkeit Neuzeitlicher Werkzeugmaschinen. Edited by Dr.-Ing. H. Opitz. 188 pp., 550 illustrations. Publishers: W. Girardet, Essen, Germany. Price: 36 DM.

This publication on the output and efficiency of modern machine tools details the proceedings of the 6th Machine-Tool Symposium, held at Aachen in 1953. It refers to the trend of design among machine-tool manufacturers in various countries and discusses, concisely and practically, modern conceptions of the construction, application, and utilisation of machine tools for the performance of cutting operations.

It also deals with economic considerations, from the viewpoint of both the manufacturer and the user, so that the book, which is excellently produced and magnificently illustrated with photographs and line drawings, is undoubtedly of great value to all those who are interested in rationalised production and increased output.

ERRATUM

On page 111 of our issue for March 1954, mention was made of the Klement Gottwald factory in Czechoslovakia. We have been informed by the author of this article that the factory in question is actually in Budapest, Hungary, and was formerly known as the Ganz Electrical Works.

LATEST INDUSTRIAL LITERATURE

1. Acoustic Mill-Feed Controller. In an illustrated 8-page booklet, details are given of an acoustic mill-feed controller, designed to provide an automatic control over the feed rate to ball-type tube grinding mills, based on an acoustic assessment, *via* a microphone, of the significant parts of the overall noise-frequency spectrum. Its chief application is in coal-pulverising mills of all capacities, but it can also be used with ball mills for grinding other materials, and may be applied in all industrial requirements where a high degree of noise discrimination forms the basis for manual or automatic control.

2. Threading Machines. Details of a range of machines for threading up to 12-in. pipes and 4-in. bolts, manufactured by a firm which has specialised for over 75 years in threading equipment, are contained in a folder, which describes and illustrates a selection from each of the different types of machines in the complete range.

The machines have been divided into four main groups, i.e., universal screwing machines, machines fitted with patent releasing-type diehead, machines fitted with patent stationary-type tangential diehead, and machines fitted with patent rotary-type tangential diehead, respectively.

3. Woodworking Machinery. Details of a comprehensive range of woodworking machinery for instructional purposes are given in a well produced and illustrated 24-page brochure. The machines described are all standard machines in daily use throughout the woodworking industries, but at the same time are not too large in capacity. Furthermore, special care has been taken to provide protective devices and guards, so as to reduce the risk of accident to an absolute minimum. In this connection, all these machines meet stringent Home Office regulations relating to the guarding of machinery.

The range of equipment described includes circular saws, band saws, planing machines, shapers, lathes, borers, etc.

4. Ceramic Capacitors. Full specifications, with excellent illustrations in colour, of a comprehensive range of capacitors for television, radio, and electronic equipment are contained in a neatly produced loose-leaf folder.

The range comprises fixed ceramic capacitors and variable capacitors, including receiver type (silvered ceramic dielectric), pearl capacitors, disc capacitors, tube capacitors, by-pass (bushed) capacitors, stand-off chassis mountings, rotary-type trimmer capacitors, high-tension ceramic trimmer capacitors, and wire trimmer " tear-off " capacitors.

5. Process Controller. A leaflet describes and illustrates an instrument which, although originally designed for controlling the process of rubber vulcanising, is not by any means limited to that application. In its original use, it provides a means of setting and controlling automatically the " blow out," the rising period and air-vent settings, and the total curing time and temperature.

The instrument can be adapted for various other processes where programme control is required.

6. Water Removal and Anti-Rust Treatment. A leaflet describes and illustrates a simple, efficient, and economical tool-treatment plant for water removal and anti-rust treatment. The plant, the overall dimensions of which are only 28 in. × 22½ in. × 36 in. in height, with a dipping tank capacity of 25 gallons, is used in conjunction with a special de-watering and rust-proofing fluid, which is a solvent-type preventive embodying water-displacing properties and the ability to neutralise finger-prints.

7. Industrial Rubber Doors. Details of patent industrial rubber doors are contained in a leaflet and pamphlet.

With these doors, which are of the normal swing type, there can be no damage to trucks or loads, no noise, and no draughts. Furthermore, maintenance costs are eliminated, and accidents to personnel through crushing are completely avoided.

8. Aluminium Alloy for Bearings. Details and specifications of an aluminium alloy for bearings are contained in an illustrated 8-page brochure. This material has been subjected to extensive service trials and has shown its suitability for main bearings, big-end bearings, and cam-shaft bushes in internal-combustion engines. It has also been used successfully as bushing in large roll-neck rolling-mill bearings.

This alloy can be supplied in various forms, such as chill or gravity die-cast bars and tubes, or cast as shells, thereby eliminating an excessive amount of machining.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *STRESS CORROSION OF PLASTICS*

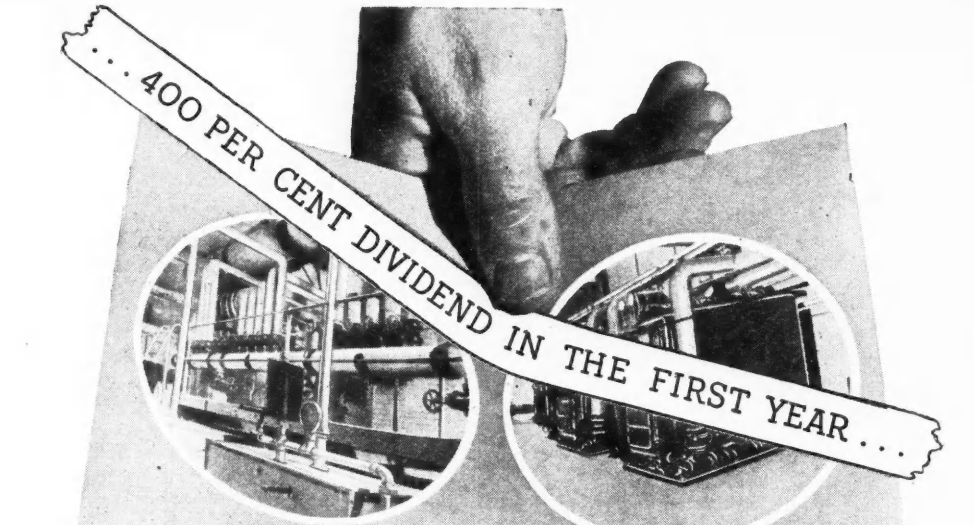
There is no doubt that a more thorough knowledge of the behaviour of plastics, insofar as manufacturing technique and mechanical design of component parts are concerned, is required in order to avoid costly setbacks which might well endanger future progress. It is therefore of more than usual interest to note that the problem of crazing in polystyrene is now coming under close scrutiny. Crazing is thought to result from localised elongations of greater magnitude than the material can accept. "Stress crazing" is considered to be associated with stresses contained in, or exerted on, the plastic moulding. These stresses may be orientation stresses caused by forced molecular alignment or disturbance during the moulding operation, or they may be packing stresses caused by the forced injection of additional polymer during thermal contraction of plastic material while cooling in the mould. Other stresses which may be present include thermally induced stresses caused by differential cooling of the plastic during the moulding process, and stresses caused by thermal shock on the entire moulding or by localised overheating of certain areas during machining and finishing operations. Finally, there are the mechanical stresses resulting from the externally applied load to which the component is subjected under service conditions. Another disturbing phenomenon is " solvent crazing," which is due to the lowering of critical elongation by the chemical action of a wide variety of agents. The rate of penetration of crazing in polystyrene has now been determined over a range of stresses, and it has been found that it is of the utmost importance in constant load application to prevent the inception of crazing, since the inevitable result of even minor crazing under these conditions is ultimate failure.

● *CONVERSION OF LIGHT INTO ELECTRIC POWER*

A solar battery has now been developed and is said to have six times the efficiency of any earlier photoelectric device. This would appear to be the first device to convert light energy directly and efficiently into useful amounts of electricity. Although the present efficiency of the experimental model of the battery is no more than 6%, it may be expected to rise considerably in the course of further development. An interesting feature is that nothing is consumed or destroyed in the energy-conversion process employed; hence, the cells should have an almost indefinite life, provided they are protected from weathering and corrosion. The salient feature of this solar battery is a strip of ultra-pure silicon, with controlled amounts of impurities diffused into its surface. When light strikes the surface of the silicon strip, its energy frees electrons or creates " holes," which are equivalent to positive electron charges, causing a potential difference to occur across the silicon strip. A number of strips, which are approximately the size of razor blades, can be connected in series or in parallel, as required. The output of the battery is roughly 50 watts per square yard of surface exposed to bright sunlight. There is no doubt that the advances in metallurgy and physics which had to be achieved in order tc arrive at this result will have important repercussions in the entire field of electronics and semiconductors. Although climatic conditions will necessarily restrict the use of the solar battery to countries favoured with a sunny climate, the tremendous technical advance indicated by this achievement cannot be exaggerated.

● *APPLICATION OF INFRARED SPECTROSCOPY TO QUANTITATIVE ANALYSIS*

It is becoming increasingly recognised that infrared spectroscopy offers an ideal method of process control; it is already being adopted as a highly reliable means of matching non-metallic materials, identifying substances of unknown composition, detecting faults, etc. Another less well known application is the application of infrared spectroscopy to accurate quantitative analysis. To mention a case which is representative of latest practice, infrared analysis is now being used to estimate the extent of depletion of corrosion inhibitors present in gas-turbine test-stand oils. Certain corrosion inhibitors are designed to cling to the metal components of the turbine to protect it from rust during shipment. The infrared test of the oil makes it possible by simple calculation to determine the amount of inhibitor concentrate which should be added to used oils to restore the oil to a proper level of rust protection. In research, infrared spectroscopy is an important tool for the study of single crystals and fibres. While the infrared spectrum extends from 0·78



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to 300 microns, the range generally used in infrared spectroscopy covers 25 to 50 microns. Briefly stated, this technique utilises the fact that molecules vibrate at various frequencies. The infrared spectrometer produces an infrared absorption curve or spectrogram with bands representing absorbed energy. These bands are characteristic of the material under infrared radiation, and their intensity is directly proportional to the amount of material causing absorption. This feature enables quantitative and qualitative analysis to be made simultaneously. Two types of infrared spectrometers are available, the single-beam and the double-beam type. The latter, which is the more elaborate, yields spectrograms on a transmission *versus* wavelength chart, so that no calculations and plotting of graphs are required.

● *MOIST-AIR HEAT EXCHANGERS*

In air conditioning the problem frequently arises of designing heat exchangers in which the surface temperatures are wholly or partly lower than the dew point of the air. In such heat exchangers, the moisture contained in the air is partly condensed, and the water transfers a certain amount of heat over and above that quantity of heat which is transmitted when no condensation takes place. In heat exchangers of the most common type, air is cooled as it passes over coils or tubes carrying water, brine, or various refrigerants. There are, however, other types of heat exchangers; for instance, the heat contained in warm, exhausted, moist air is sometimes utilised to heat cold, fresh air. Both in air coolers and in fresh-air heaters, it is the air that is cooled, with the result that moisture in the air undergoes condensation. In other cases, again, e.g., in evaporative condensers, the surface is warmer than the air, but the surface is kept moist, so that heat is transferred by evaporated moisture from the warm surface to the cold air. The author of a recent paper has evolved an accurate and easily applied method of computing and designing moist-air heat exchangers. The main difficulty encountered in the design of moist-air heat exchangers lies in the determination of the temperature of the surface on which the condensation of the water vapour contained in the air or the evaporation of the water takes place. In heat exchangers of the extended-surface type, this surface is provided with fins, and is therefore much larger than the surface on the other side of the heat-exchanger wall. For this reason, the temperature of this surface cannot be assumed to be equal to the temperature of the fluid passing on the other side of the wall, even if the coefficient of heat transfer from this fluid to the wall surface of the heat exchanger is high. It may possibly also be necessary to take into account the fact that the temperature of the inner part of a fin, close to the tube, is not equal to that at the outer edge of the fin.

● *COATING METALS WITH ALUMINIUM*

There is no doubt that, for the protection of iron and steel against corrosion, aluminium offers definite advantages. However, the use of aluminium for this purpose has been extremely restricted because of the difficulty of producing an adherent aluminium coating on iron and steel surfaces, as compared with galvanised coatings. As a coating metal, aluminium is the superior of the two metals, since it forms a continuous, adherent, and inert oxide film, while zinc forms a hydrated, loosely adherent oxide film. Moreover, for the same thickness of protective coating, aluminium has the advantage that the weight of an aluminium coating per unit of surface is only about one-third of that of a corresponding zinc coating. However, no difficulties exist in producing zinc coatings on iron and steel surfaces, while aluminium coatings have hitherto been found most difficult to produce. According to a recent patent, this difficulty can be overcome by first applying a water-base fluxing compound to the surface to be coated. This flux comprises zirconium fluoride or titanium fluoride, either alone or as a complex salt of zirconium fluoride or titanium fluoride, with an alkali metal such as potassium. After dipping the article in the aqueous solution of such a flux, it is permitted to dry, so that an adherent coating of finely divided zirconium-fluoride compound remains on the surface. The article is then dipped into a bath of molten aluminium and, after removal, exhibits a continuous, bright coating of aluminium. It is claimed that optimum corrosion resistance is obtained if the temperature of the aluminium bath ranges from about 1220 to about 1240° F. After the coating has solidified, it is quickly cooled by a quench in cold water, in order to retard the formation of a brittle aluminium-iron alloy.

● *ELECTROMAGNETICALLY OPERATED REFRIGERATOR COMPRESSOR*

A recent patent specification describes in detail the design of a novel refrigerator compressor in which the conventional motor drive is replaced by an electromagnetic reciprocating system. The main purpose of this invention would appear to be the creation of a refrigerator unit of relatively small capacity, of the type used for domestic purposes, shops, etc. The advantage of the design envisaged would appear to lie in the fact that vibratory devices of the type used do not require lubrication and can operate in a hermetically sealed vessel containing refrigerant. Moreover, by elastically suspending the compressor in the casing, noise and vibration of the unit appear to be reduced to a minimum. The compressor proper consists of two compressor pistons working in opposition and supported by two vibrating spring blades. To these spring blades are attached permanent magnets which constitute armatures,

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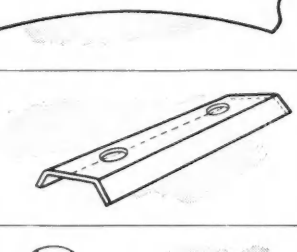
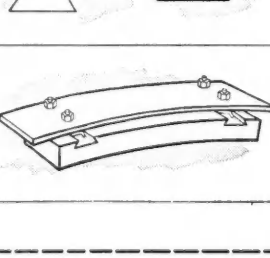
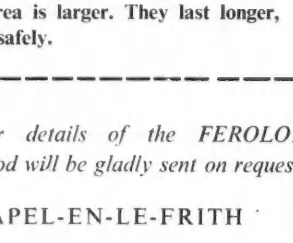
The Ferodo Lining is supplied radiused and grooved.



FEROLOK "keepers" fit firmly into the grooves. Keepers are made in sizes suitable for linings $\frac{1}{2}$" thick and upwards.



FEROLOK bolts hold the keepers securely in the grooves and the dovetail action keeps the lining securely fastened to the band.



When the bolts are loosened, it simply slides into position (as shown). The nuts are then tightened and the job is done.

FEROLOK fitted linings have no rivet holes, and therefore, their working area is larger. They last longer, more safely.

To reline, four simple operations are required. 1. Slacken off the bolts. 2. Slide off old lining. 3. Slide on new lining. 4. Retighten bolts.
Note: Shoes or bands remain in position all the time.

The FEROLOK method of fitting linings is equally suitable for both internal expanding and external contracting brakes.

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the latter being attracted at network frequency by electromagnets. The blocks of the two cylinders are mounted on the opposing faces of a hollow casting, which acts as the refrigerant receiver. The pistons, which are carried by the leaf springs, are made of a special rubber or some other material suitable for the purpose. The leaf springs are designed to have a natural period of vibration which is lower than that of the frequency of the electric current supplied to the exciter coils. In order to keep vibration and noise of the unit to a minimum, the two pistons are arranged to effect compression simultaneously, so that driving forces and inertia are constantly in opposition. The cylinders are closed at their outer ends by flexible rubber sealing caps, and the valves of the compressor are also made of rubber.

● *IONIC HIGH-VACUUM PUMP*

The ionic pump is a comparatively new device for the production of high vacua. Experimental units are reported to have given highly satisfactory results, having produced vacua as high as one-thousand-millionth of normal atmospheric pressure. It is therefore considered possible that this type of vacuum pump may eventually simplify evacuation of radio valves and other vacuum tubes. One form of the new pump consists of a circular stainless-steel box, supported between the poles of a powerful permanent magnet and connected to the vessel to be evacuated. Inside the box is a tungsten ring connected to the positively charged side of the high-voltage circuit supplying the pump. The metal walls of the box are connected to the negative side of the circuit. Rough evacuation is effected by means of an ordinary mechanical pump, and when a certain vacuum is reached the ionic pump is connected and electric current is switched on, so that an electrical gas discharge occurs. Electrons are attracted towards the tungsten ring, but the field of the magnet causes them to oscillate. During oscillation, electrons collide with gas atoms, which become ionised and are pulled towards the pump walls. On the way, they contact carbon plates, where they are held. Thus, the gas pressure is reduced, and the absorbed gases can be driven out of the carbon plates by heating the pump. This new pump is reported to work on practically all gases. It is considered that, for some special applications, a pump of this type might be permanently attached to the tube in which constant vacuum is to be maintained.

● *PROBLEMS OF LIQUID-METAL CORROSION*

The introduction of molten sodium, fused fluorides, and hydroxides into nuclear-power reactor technique is opening up a new phase of corrosion technology. When using the term " corrosion " in connection with these substances, it must of course be realised that in these cases corrosion involves solution without oxidation, i.e., a mechanism not present in aqueous corrosion. The solubility of many metals in liquid sodium increases with temperature, and in a system having a temperature gradient, sodium may therefore dissolve metal at higher temperature and deposit at points of lower temperature. It need hardly be stressed that a mass transfer of this nature can cause a great deal of damage by plugging tubes. Another type of attack is caused by the differential solubility of various alloying components in a metal. Copper-based tin alloys cannot be used, nor can silver solder. This is unfortunate, as silver solder is often desirable in fabricating equipment for liquid-sodium systems. Another difficulty encountered in sodium systems is caused by diffusion bonding, i.e., bridging between adjacent parts, causing mating. The separation of parts bound together will be difficult, if not impossible, and in certain cases it may even be impossible to detect a dividing line. Ceramic materials are used in molten-sodium systems for seals or for back-up devices, to ensure safety in case of failure of metallic pressure-measuring diaphragms. Ceramic materials may be soluble or they may be merely porous on coming into contact with liquid sodium. Water coming into contact with sodium which has penetrated the pores of a ceramic material may cause it to shatter. These examples are only a few among a host of problems confronting the designer of nuclear-power reactors.

● *EFFECT OF ULTRASOUND ON THERMOPLASTIC MELTS*

Mixing and homogenising steps are of particular importance in the manufacture and compounding of thermoplastic material. An investigation was recently undertaken with a view to studying the effect of ultrasound upon molten thermoplastics, in order to survey the potential importance of ultrasonic energy in the processing of those materials. In carrying out this investigation, particular attention was paid to the following points :—(1) The effect of ultrasound upon the molecular weight of polymer melts. (2) Heating of polymer melts through the absorption of ultrasonic energy. (3) Molecular orientation through ultrasonic energy. (4) Effectiveness of ultrasound in dispersing and homogenising pigments and fillers in polymer melts. (5) Effect of ultrasonic energy upon the viscosity of polymer melts. The apparatus employed in this study consisted of a piezo-electric ultrasonic generator which could produce frequencies ranging from 350 kc to 3000 kc at energy levels of from 3 to 5 W/cm^2. Standard moulding-powder grades of polystyrene, polyethylene, and polyvinyl chloride, containing 50% dioctyl phthalate, were used in these experiments at temperatures between 200° C and 270° C. It was found that ultrasonic energy has no depolymerising effect upon the molten thermoplastics, but that its absorption causes a rapid rise in

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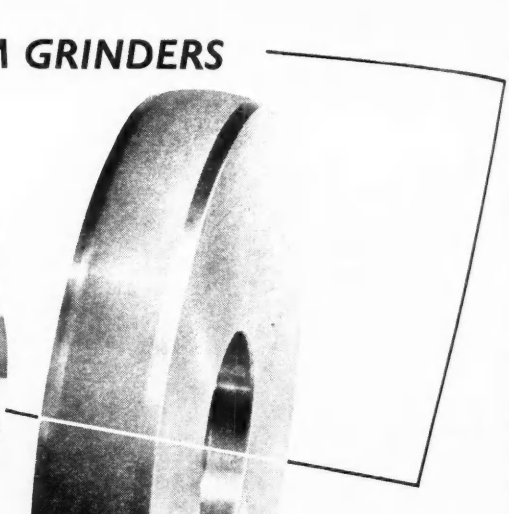

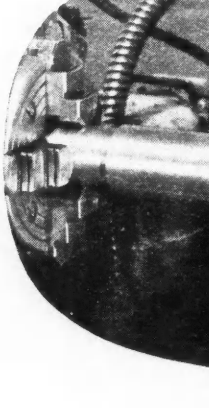

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temperature. Ultrasonic energy was observed to cause molecular orientation in a plane perpendicular to the direction of the sound waves ; it could be used to aid in the homogenisation and in the dispersion of colourants and fillers in plastic melts. The fact that ultrasound does not degrade the molecular structure of plastic melts suggests that it may be considered for a number of possible future applications in plastics processing.

● *ALUMINIUM-MOLYBDENUM-IRON ALLOYS*

The development of an aluminium-molybdenum-iron alloy with oustanding oxidation and corrosion resistance has recently been announced. The new alloy, which is said to show considerable promise as a high-temperature, high-strength material, contains 15 to 16% aluminium and 3% molybdenum, the balance being iron. It is a modification of an earlier alloy containing 16% aluminium. While the composition is not new, considerable research had to be carried out in order to find the proper procedure for rolling the alloy into thin sheet, including foil. It has been found possible to produce a foil 0·0003 in. thick by cold rolling. Particular advantages claimed for aluminium-iron alloys for jet engine and other aircraft applications are their lightness. For instance, their specific gravity is some 20% less than that of stainless steel. In fresh-water and sea-water corrosion tests, the iron-aluminium alloys were found to be superior to steel and cast iron and to have roughly half the corrosion resistance of stainless steel. Unfortunately, the original report from which this information is derived does not identify the stainless steel used in this case as a basis for comparison. The addition of aluminium to iron results in a marked increase in oxidation resistance in air at high temperature. It has been stated that a 14% aluminium-iron alloy was in good condition after six months in a sulphur-burning furnace atmosphere at a temperature of 950° C. The major difficulty in connection with aluminium-iron alloys is the brittleness of the as-cast material and its cracking during rolling to shape. The major significance of the recent progress referred to above would therefore appear to lie in the achievement of a technique for producing these alloys in sheet form.

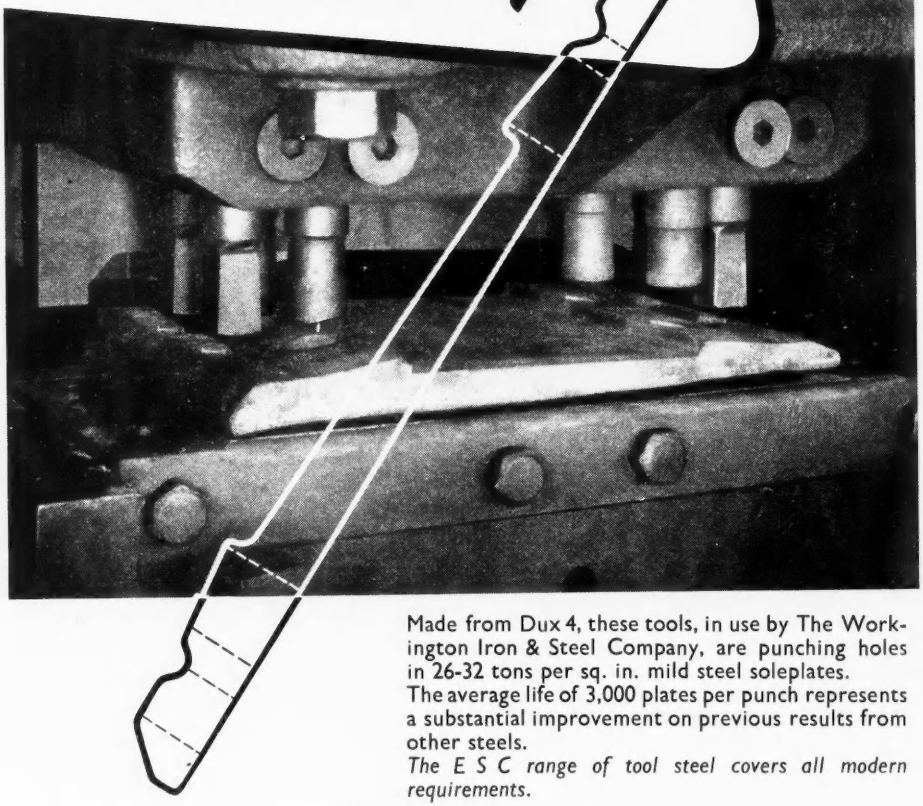
● *HEAT-REFLECTIVE PAINT*

A heat-reflective coating for exterior surfaces is claimed to be highly effective for keeping buildings cool in hot climates. It is reported that this paint will lower the temperature inside a galvanised-steel building to within 1° F of the shade temperature and that temperatures under a steel roof have been reduced by as much as 45° F in summer weather. In the case of an asphalt roof, the temperature can be lowered by some 30° F. The " coolness " of the new paint depends upon the reflective qualities of the pigment combination used. To reflect heat waves, it is not necessary for the paint to be extremely white. In fact, since the pigment used contains titanium dioxide, its whiteness tends towards yellow rather than blue, but this holds no disadvantages as regards reflectivity. Whiteness of the coating is effective only in the visible spectrum. The remainder of the reflectivity is in the invisible (infrared) range, and therefore does not depend on degree of whiteness for maximum efficiency. The film thickness required for most applications will depend upon the colour of the surface to which it is applied, as a completely opaque coating must be created for maximum efficiency. The new paint can be applied by any conventional method, but a considerably thicker coating than usual must be used. It is further claimed that the painted surfaces resist mildew and mould growth, as a bactericide and a fungicide are incorporated. The new paint may also prove useful in the painting of chemical barges and storage tanks, to reduce losses by evaporation. Tests are now under way to ascertain its salt-spray resistance.

● *GRINDING OF TITANIUM*

Considerable difficulties have been experienced in the grinding of titanium, since the grinding of this material sets up high, localised temperatures at the point of wheel contact, and the metal apparently combines chemically with wheel materials. The grinding process may be considered as a machining process in which an extremely large number of small single-point cutting tools is employed. In this process each small grain of abrasive material in the contact area of the wheel must remove a tiny chip from the material being ground. Since resharpening of individual grains is, of course, impossible, the grain must break away, leaving a fresh, sharp cutting surface at the wheel's next revolution. If breaking-away does not take place fast enough, the wheel will become glazed or loaded, and the relatively smooth surface will burnish the metal surface. This will cause a sudden, rapid rise in temperature, with consequent burning and cracking. Early attempts to grind titanium, particularly high-carbon or high-oxygen alloys, were disappointing. In fact, grinding of titanium was almost considered impractical as a manufacturing technique. Certain alloys were found to be prone to grinding cracks and distortion because of notch sensitivity, high stresses, and poor dissipation of heat. The rate of wheel wear, from the aspects of cost and grinding accuracy, was almost prohibitive ; in some cases one to two pounds of wheel were lost for each pound of metal removed. However, persistent research has now shown that satisfactory results can be obtained by the choice of a proper speed which is usually below that used for other metals, while the addition of special chemical compounds to the coolant will inhibit the reaction between the titanium and the grinding wheel.

Dux 4 Tool Steel punching 8 holes simultaneously



Made from Dux 4, these tools, in use by The Workington Iron & Steel Company, are punching holes in 26-32 tons per sq. in. mild steel soleplates.
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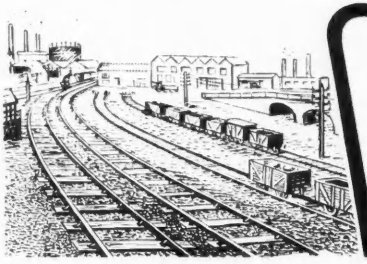

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